ACCESS MACQUARIE LIMITED
ABN 59 003 849 198

UPPER HUNTER OSIRIS STUDY

Initial report - Assessment and cross-calibration of OSIRIS monitors May – September 2011 Prepared for NSW Health

(CONTACT: WAYNE SMITH)

A.L. MORRISON, J.S. BAKKER AND P.F.NELSON
GRADUATE SCHOOL OF THE ENVIRONMENT
MACQUARIE UNIVERSITY

NOVEMBER 2011

1 Project Objectives

1. To measure fine particulate concentrations (PM1, PM 2.5 and PM 10) at a range of relevant sites across the Upper Hunter for future population exposure assessments.
2. To test the hypothesis that spatial variation in fine particle pollution (PM2.5 and PM1) across the Upper Hunter Valley is small enough that exposure can be well characterised by measurement at 3 monitoring sites (Singleton, Muswellbrook and Camberwell).

2 Initial Report Requirements

1. Milestones/Summary of data availability from the OSIRIS instruments and report of any maintenance issues.
2. Scatter plots of 24-hour averages comparing results from the different OSIRIS instruments/sites for PM10, PM2.5 and PM1. Report correlation coefficients.
3. Comparison of OSIRIS measurements with PM10 and PM2.5 data provided by OEH from their co-located instruments at the monitoring sites. Present as scatter plots with linear best fits through the origin and correlation coefficients.
4. Assess spatial variability of PM concentrations across the sites.
5. Suggest any improvements in the measurement program that would enable it to better meet the stated objectives of this project.
6. Reports to include raw and quality controlled data in digital form. Data will also be supplied to OEH. These data will not be published on-line.

3 Background

Three OSIRIS[1] instruments (S/N 3054, 3055 and 3056) were co-located at the Office of Environment and Heritage (OEH) monitoring site at Civic Avenue next to the Civic Centre in Singleton (32.5574 deg S, 151.1770 deg E),monitoring Total Particles, PM1, PM2.5, PM10, windspeed and direction, from the 2nd of May to 22nd August 2011. Figure 1 shows the site location. The purpose of this phase of the project was to cross correlate individual instruments, to familiarise OEH technicians with the instruments and to make an assessment of the operability of the OSIRIS instruments in the field.

4 Results and Discussion

4.1 *Data Availability and Maintenance Issues*

Data at 10 minute intervals, from all three instruments was continuously recorded from 2nd May - 22nd August 2011, when the instruments were shut down prior to relocation. There were monthly minor losses of data of up to one hour when the OSIRIS filters were changed. Data availability for the period was greater than 99.8%.

[1] www.turnkey-instruments.com

A trial of running the instruments (M. Hibberd, CSIRO) without inlet heaters (25th – 30th May) proved unsuccessful and data from this period has not been included in subsequent analysis.

Occasional individual data points have been lost, usually at the midnight zeroing of the instruments, and it is believed that this may be a minor aberration in the OSIRIS software. All data omissions are included in a log as Appendix A to this report.

Figure 1 OEH monitoring site, off Civic Avenue, Singleton, NSW.

Some variations with instruments clocks were noted at the time of the monthly OSIRIS filter change. This resulted in the following variations in clock times between the instruments (Table 1).

OSIRIS	2nd May	31st May	30th June	28th July
3054	0	0	+ 4 minutes	+ 5 minute
3055	0	+ 4 minutes	+ 8 minutes	+ 10 minutes
3056	0	+ 5 minutes	+ 10 minutes	+ 12 minutes

Table 1 Cumulative time differences[2] recorded between instruments and standard time at monthly filter changes.

[2] Time base was mobile phone and OEH data logger time

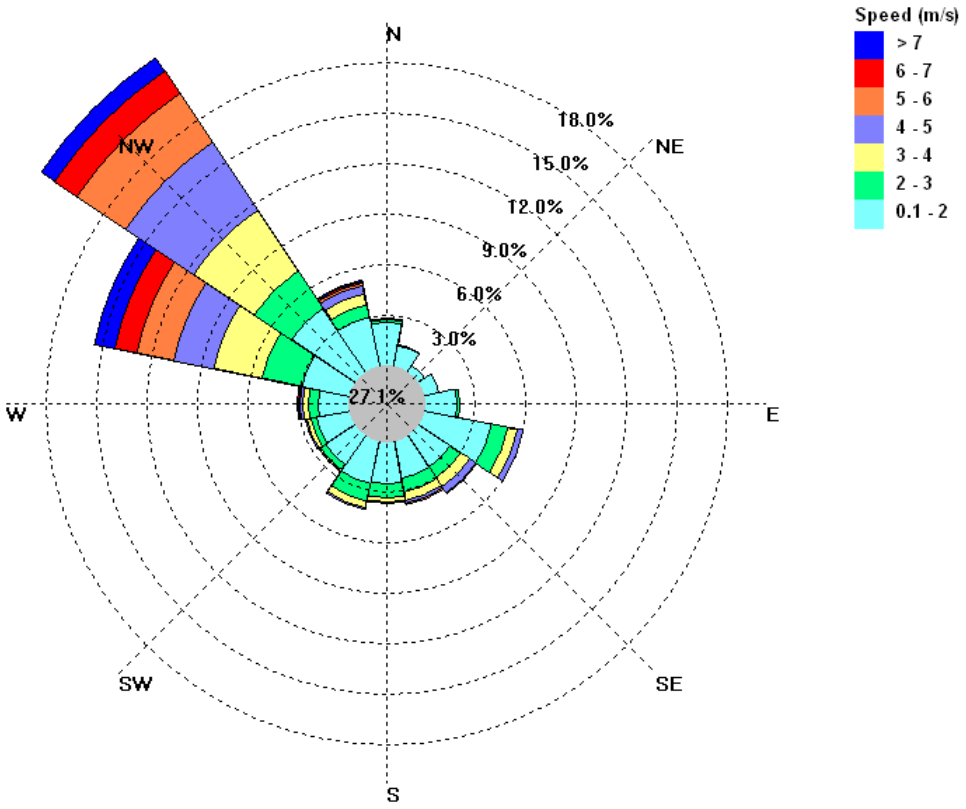
These time variations created problems in assessment of short sampling time data, particularly during periods of high transient particulate events. However, when data is averaged over 24 hours the effect should be minimal.

Following representations to Turnkey (the supplier of the OSIRIS instruments) a "fix" for the problem has been developed, which will involve the individual instrument clocks being reset each 24 hours to the computer time when data is downloaded. A revised EPROM was fitted to all instruments prior to relocation (22nd of August), this should enable the time correction to be implemented. It will be possible to confirm that this has occurred at the next filter change following relocation, when the time differences between machines are again noted.

4.2 *Windspeed (WS) and Direction (WD)*

Meteorological measuring equipment was fitted to one of the OSIRIS instruments (3054). Data collected for WD [magnetic north (N)] and WS. When WS fell to <0.1 m/s it has been noted as "calms" (central grey area in chart), as any measured directional output is misleading and simply reflects that last reading taken.

Figure 2. Wind direction [magnetic north (N)] and speed during the instrument co-location test period 2nd May- 22nd August, [calms <0.1 m/s (grey central area) WD not determined]



As might be expected in the Hunter Valley during the winter period the wind direction was dominated by NW winds except when wind speeds were light (0.1 – 2 m/s).

4.3 *Time Series OSIRIS 3054 (May – August 2011)*

Figures 3 and 5 show 24 hour averages time series data for OSIRIS 3054 collected during the sampling period 2nd May- 22nd September 2011 at the OEH Singleton sampling site.These values are all below the 50µ/m^3 NEPM guideline. There has been no attempt at this stage of the project to further analyse these data to determine whether the high values are a result of particular meteorological conditions.

Figure 3 PM10 time series data (24 hour averages) for the OEH Singleton monitoring site, 2nd May -22nd September, 2011.

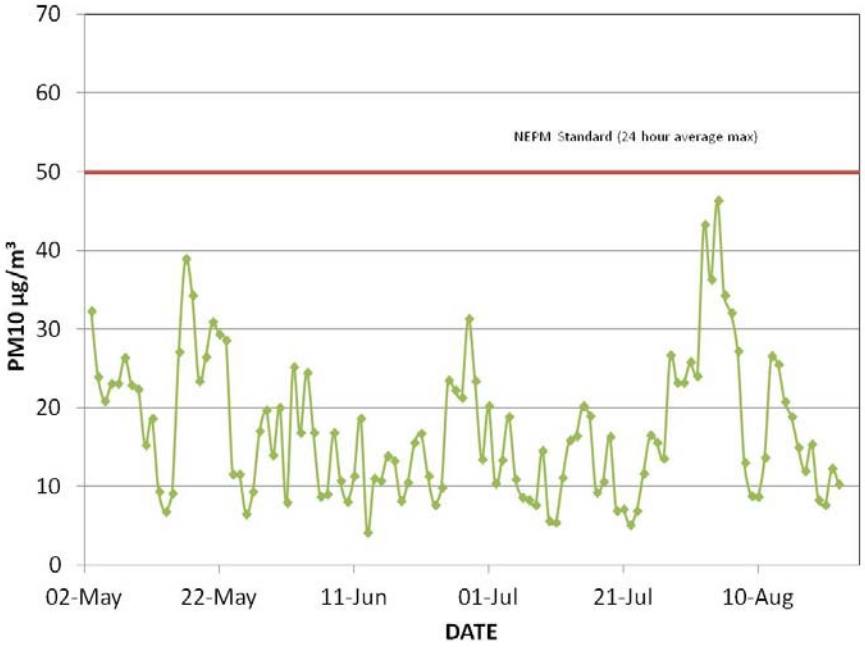


Figure 4 PM2.5 time series data (24 hour averages) for the OEH Singleton monitoring site, 2nd May -22nd September, 2011.

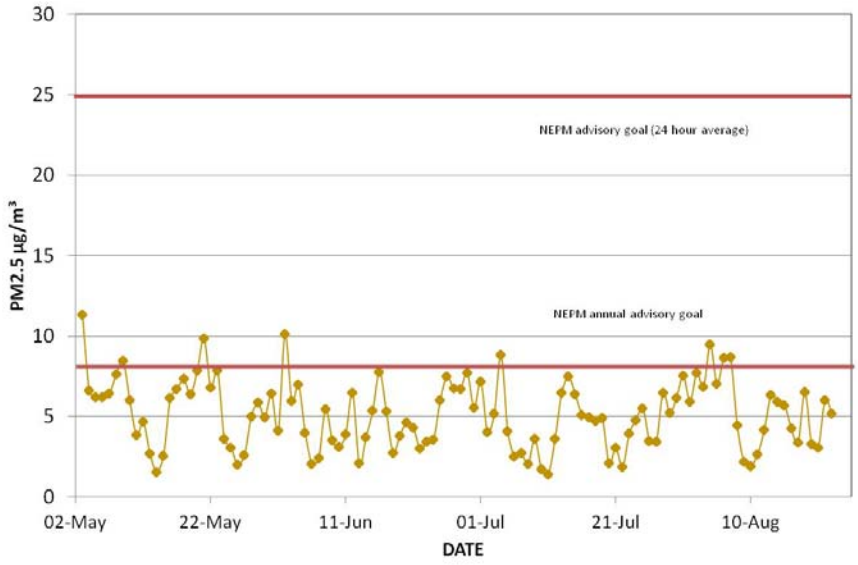
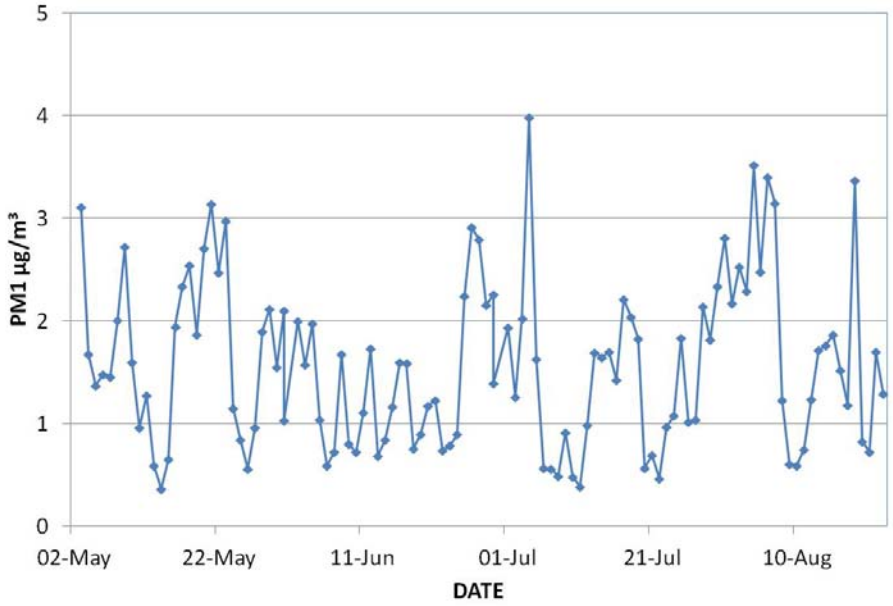


Figure 5 PM1 time series data (24 hour averages) for the OEH Singleton monitoring site, 2nd May -22nd September, 2011.



4.4 *Scatter Plots of Individual OSIRIS Instruments*

Scatter plots were used to compare the data recorded, by the three OSIRIS instruments. The scatter plots below show 24 hour averages for PM1, PM2.5 and PM10, using OSIRIS 3054 as the base instrument. Statistical values [slope, coefficient of determination (R^2) and standard error (SE)] were determined using the Microsoft Excel trendline function and statistics package. The results in all cases were fitted to a linear function of the form:

$$\text{OSIRIS (TEST INSTRUMENT)} = \text{slope} * \text{(OSIRIS 3054)} \qquad (1)$$

i.e. a linear trendline was forced through the origin.

PM10 (Figs 6 and 7) – very strong positive linear correlation for all OSIRIS instruments (R^2 both of 0.98). Slopes of 0.91 (3055) and 0.93 (3056) indicate slight under reporting of PM10 for these instruments compared to OSIRIS 3054.

PM2.5 (Figs 8 and 9) - very strong positive linear correlation for all OSIRIS instruments (R^2 of 0.98 and 1.00). A slope of 0.95 (3055) indicates slight under-reporting of PM2.5 for this instrument compared to OSIRIS 3054. The slope of 1.01 (3056) indicates very slight over-reporting of PM2.5 for this instrument compared to OSIRIS 3054.

PM1 (Figs 10 and 11) -very strong positive linear correlation for all OSIRIS instruments (R^2 of 0.99 and 1.00). A slope of 0.97 (3055) indicates slight under-reporting of PM2.5 for this instrument compared to OSIRIS 3054. A slope of 1.00 for

PM1 in comparing OSIRIS 3054 with 3056 shows there was no discernable difference between instrument outputs.

Table 2 Summary of statistics of each instrument (24 hour averages) compared against OSIRIS 3054

Compared to OSIRIS 3054	**OSIRIS 3055**	**OSIRIS 3056**	**OSIRIS 3055**	**OSIRIS 3056**	**OSIRIS 3055**	**OSIRIS 3056**
Parameter	PM10	PM10	PM2.5	PM2.5	PM1	PM1
Slope	0.91	0.93	.0.95	1.01	0.97	1.00
R^2	0.98	0.98	0.98	1.00	0.99	1.00
Standard Error	1.37	1.42	0.33	0.12	0.09	0.03

In general, the comparative results from OSIRIS 3055 show a higher degree of scatter than those from OSIRIS 3056. This can be seen in the slightly lower R^2 and higher Standard Error values (Table 2) for OSIRIS 3055 compared to OSIRIS 3056.

Based on the data in Table 2 adjustment factors for the instruments to "standardise" to the OSIRIS 3054 output are shown in Table 3. These will be used to compare results when the three OSIRIS instruments are located at different sites.

Table 3 Adjustment factors for OSIRIS to 'standardise' results to those of instrument 3054

	PM10	**PM2.5**	**PM1**
OSIRIS 3054	1.00	1.00	1.00
OSIRIS 3055	1.09	1.05	1.00
OSIRIS 3056	1.07	0.99	1.02

Figure 6 PM10 comparison of OSIRIS 3054 with OSIRIS 3055 (24 hour averages)

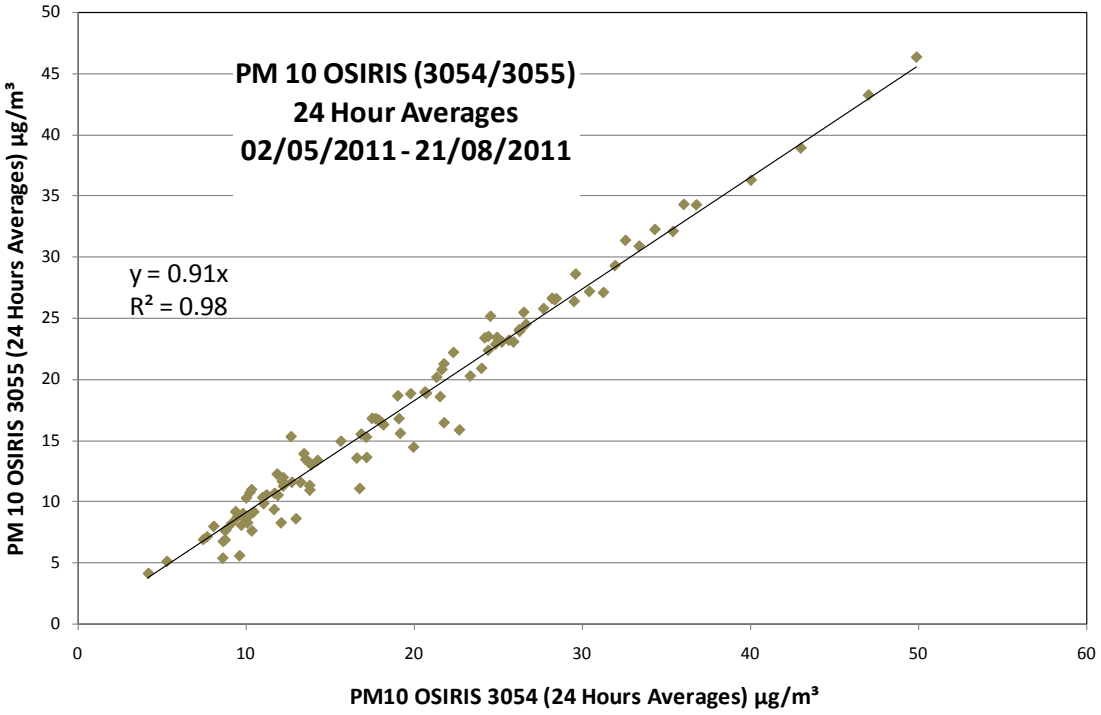


Figure 7 PM10 comparison of OSIRIS 3045 with OSIRIS 3056 (24 hour averages)

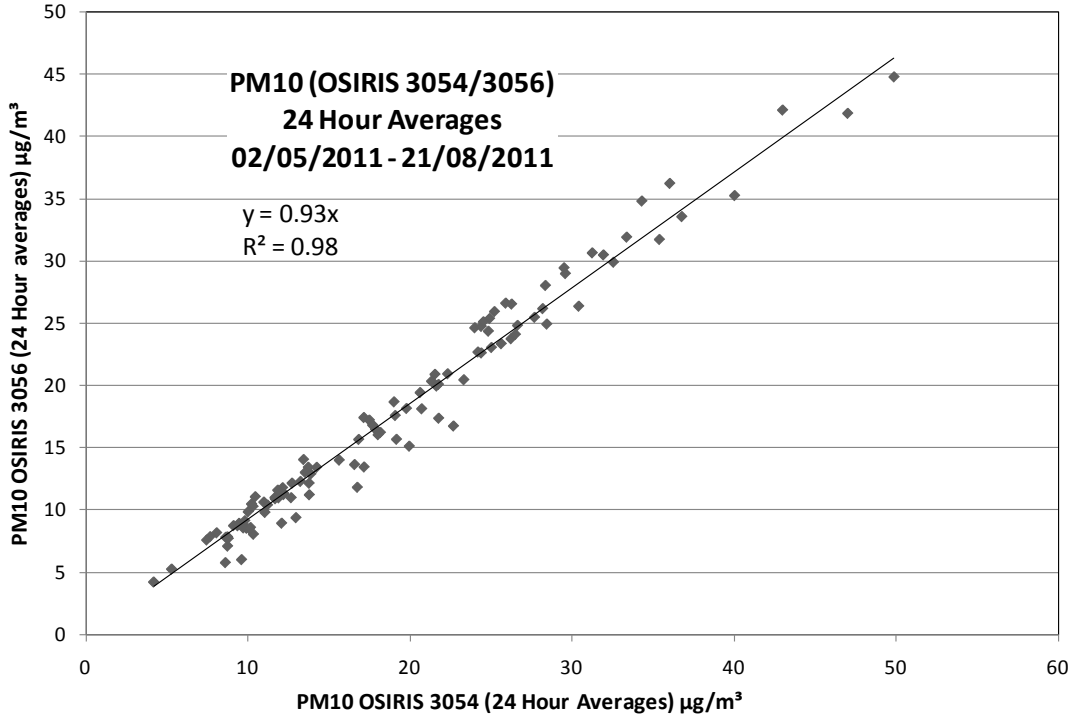


Figure 8 PM2.5 comparison of OSIRIS 3054 with OSIRIS 3055 (24 hour averages)

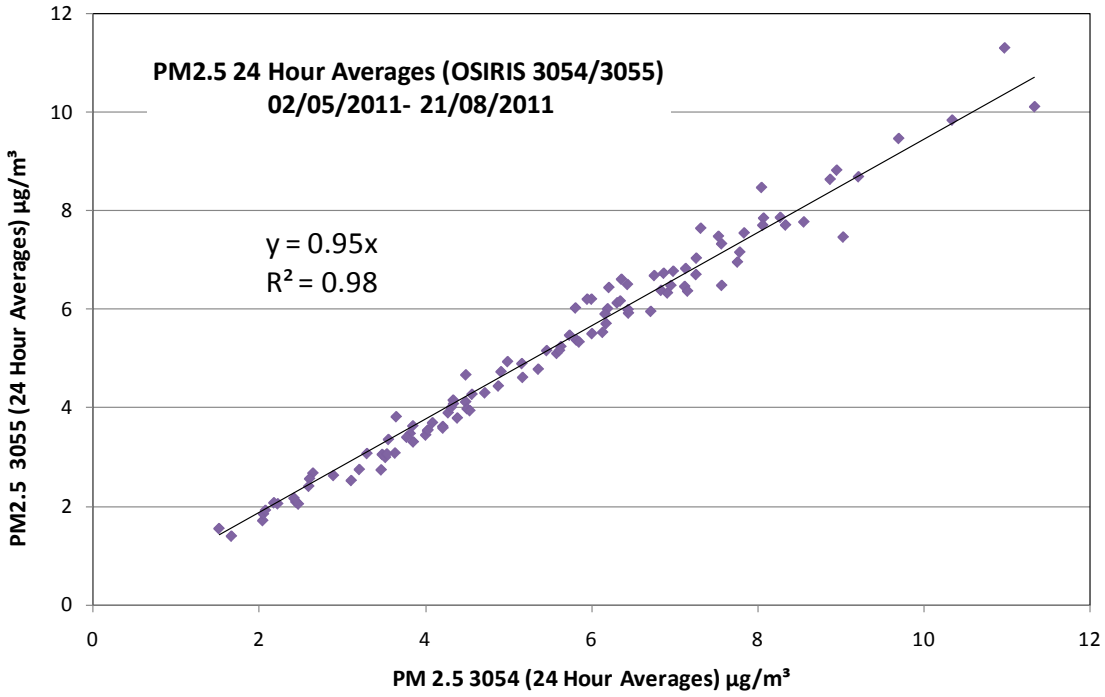


Figure 9 PM2.5 comparison of OSIRIS 3045 with OSIRIS 3056 (24 hour averages)

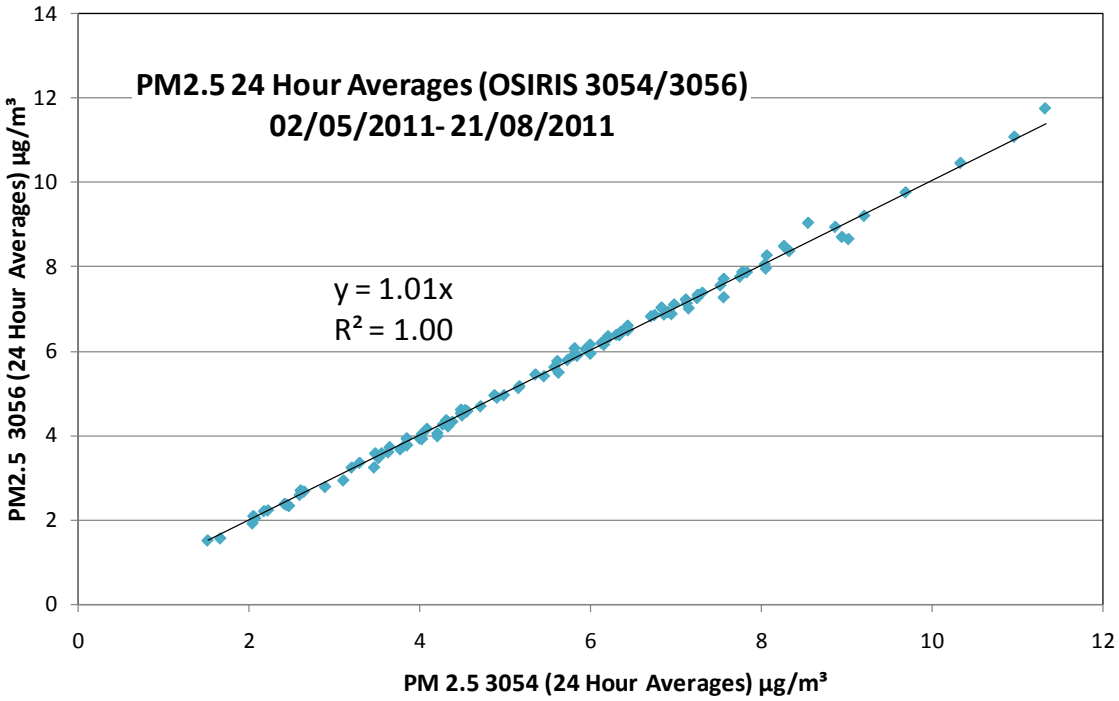


Figure 10 PM1 comparison of OSIRIS 3054 with OSIRIS 3055 (24 hour averages)

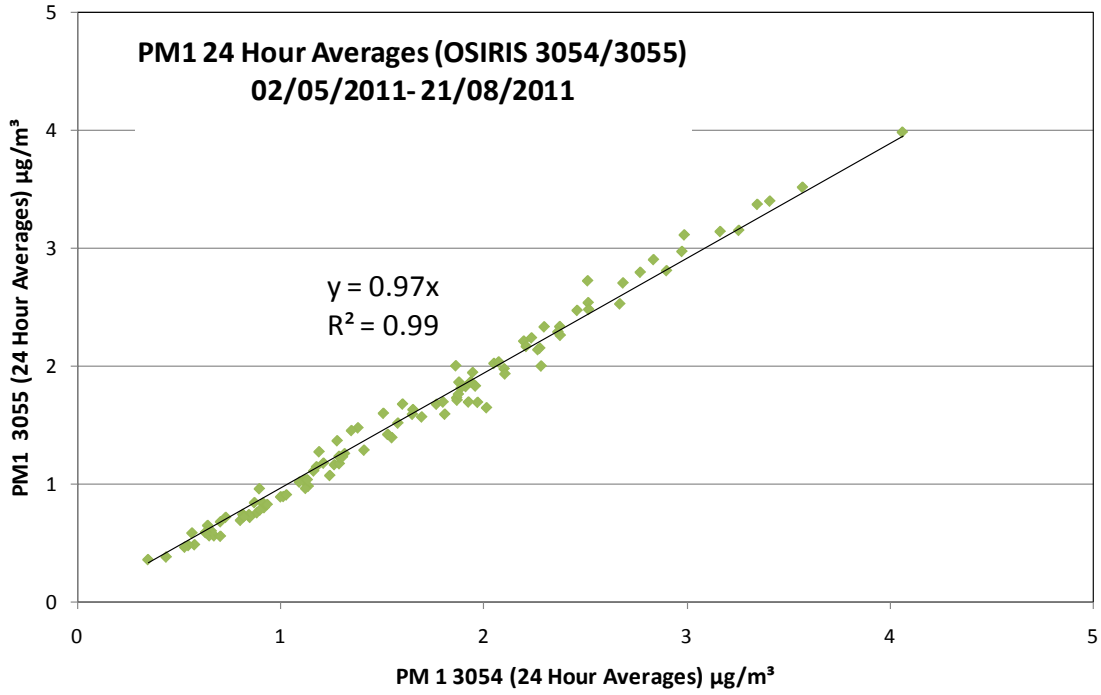
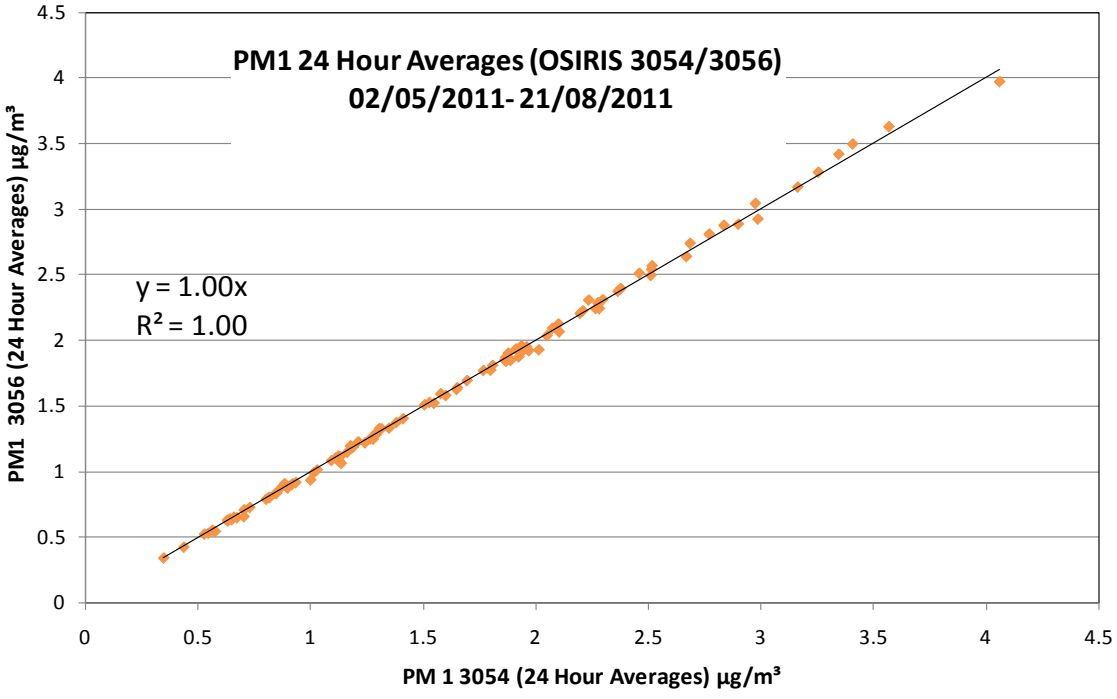


Figure 11 PM1 comparison of OSIRIS 3054 with OSIRIS 3056 (24 hour averages)



4.5 OEH TEOM (PM10) and BAM (PM2.5) Instruments

A comparison was made between the results from OSIRIS 3054 and the outputs from the co-located OEH TEOM (PM10) and BAM (PM2.5) instruments. Reported 24 hour averaged values from OEH instruments were downloaded from the OEH website[3].

Table 4 Summary of statistics of OEH instruments (24 hour averages) compared against OSIRIS 3054

Compared to OSIRIS 3054	**OEH TEOM**	**OEH BAM**
Parameter	PM10	PM2.5
Slope	0.98	1.60
R^2	0.67	0.43
Standard Error	5.18	3.53

TEOM PM10 – (Fig 12)- a strong positive linear correlation was the result when comparing the OEH TEOM with OSIRIS 3054, the slope of 0.98 (TEOM) indicates that in general there is slight under-reporting of PM10 for this instrument compared to OSIRIS 3054. There is moderate amount of scatter as indicated by an R^2 of 0.67, with an SE = 5.18. Cross-correlation between these instruments is similar to a slope of 0.95 (R^2 = 0.8) achieved previously between TEOM and OSIRIS PM10 outputs for a sampling site in Singleton Showground in 2005 (Nelson, Morrison et al. 2007).

The high degree of similarity in output from these instruments might be expected as both operate with heated inlets (~50°C) and losses of volatile components should be comparable. The degree of scatter may be attributable to the different measurement techniques used internally in the instruments i.e. mass (TEOM) versus light scattering (OSIRIS)

BAM PM2.5 – (Fig 13) – a poor positive correlation for PM2.5 was found between the OEH BAM and OSIRIS 3054. Divergence from linearity was high (R^2=0.43, SE= 3.53). The slope of 1.60 indicates that, in general, the BAM is reporting significantly higher PM2.5 results than the OSIRIS. In Figure 9 the dashed line (----) shows a bivariate 1:1 relationship between the variables.

The significant differences in output between the BAM and OSIRIS are likely to be due to the different treatment of input air samples in the two instruments. In the BAM input air is maintained at a relative humidity of less than 35% and minimal inlet

[3] http://www.environment.nsw.gov.au/AQMS/search.htm

heating is applied. This would result in a lower loss of volatile and semi-volatile aerosols than in the OSIRIS, which has its inlet air heated to ~ 50°C.

Figure 12 PM10 comparison of OSIRIS 3054 with OEH TEOM (24 hour averages)

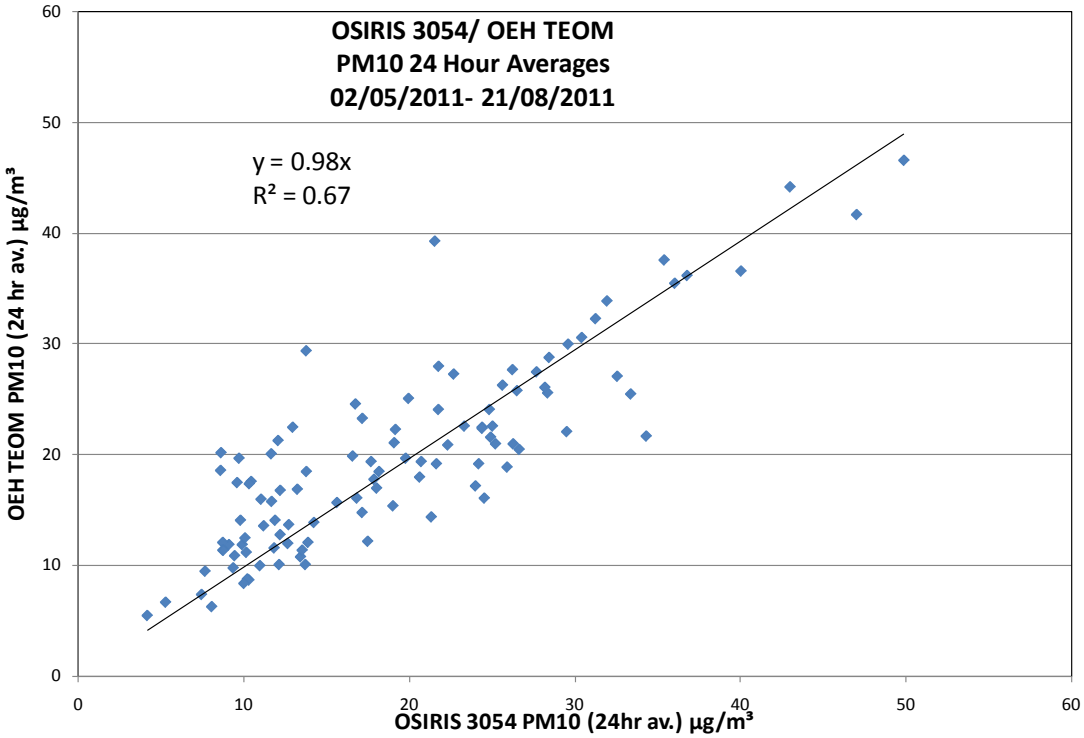
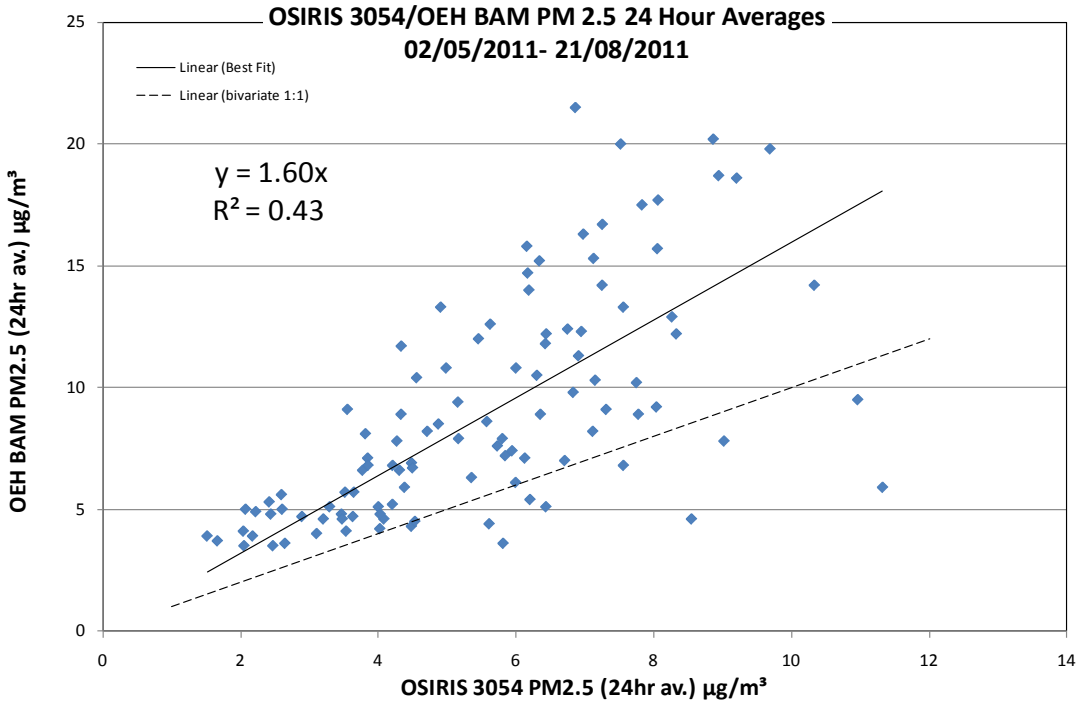


Figure 13 PM2.5 comparison of OSIRIS 3054 with OEH BAM (24 hour averages)



5 Conclusions

- A three month co-location of three OSIRIS particle analysers was carried out at the OEH monitoring site at Singleton.

- All instruments performed well and no mechanical difficulties were encountered. Apart from monthly filter changes no further maintenance was required.

- Differences in clock timings between instruments, which could have influenced the ongoing program were recognised and a strategy has been implemented which should eliminate this issue for the ongoing project.

- A high degree of correlation between the OSIRIS instruments was measured, differences between machine outputs were small. The robustness of this outcome should confidently allow adjustment (normalisation) of results from the individual instruments in this ongoing program.

- Comparison of 24 hour averaged PM10 results from the OSIRIS and from a co-located TEOM show a strong correlation and a slope of 0.98.

- Conversely, 24 hour averaged PM2.5 results from the OSIRIS and a co-located BAM show a great deal of divergence from linearity (R^2= 0.43) and a slope of 1.60. These results suggest that it will be difficult to compare OSIRIS and BAM results in the longer trial period.

6 Reference

Nelson, P. F., A. L. Morrison, et al. (2007). Characterising and assessing fine particle concentrations in the Hunter Valley - Implications of the National Environment Protection Measures for the coal mining industry. Pullenvale, Qld, CRC for Coal in Sustainable Development: 74.

APPENDIX A

OSIRIS ERROR LOG – May-September 2011

ERROR	OSIRIS #	Measurement	Time	Comments
Negatives	3054	PM1	12/05/2011 10:10-11:00	6 negative values
Blanks	3054	Total Particles/ PM10/PM2.5/PM1	25/05/2011 18:30- 30/05/2011 12:20	
Blank	3054	Wind Speed and Direction	25/05/2011 18:30	
Blank	3054	Wind Speed and Direction	25/05/2011 12:20	
Blank	3054	Wind Direction	20/05/2011 0:00	
Blank	3054	Wind Direction	24/05/2011 0:00	
Blank	3054	Wind Direction	07/06/2011 0:00	
Blank	3054	Wind Direction	24/06/2011 0:00	
Blank	3054	Wind Direction	29/06/2011 0:00	
Blank	3055	PM1	10/05/2011 0:00	
Blank	3055	PM1	21/05/2011 0:00	
Blank	3055	PM1	26/05/2011 0:00	
Blank	3055	PM1	31/05/2011 23:56	
Blank	3055	PM1	24/06/2011 0:00	
Blank	3055	PM1	29/06/2011 0:00	
High data point	3055	Total particles	20/05/2011 6:30	Large data point of 873.7 µg/m^3. No wind speed. There was quite a large value for OSIRIS 3054 (395.2 µg/m^3) and OSIRIS 3056 (97.9 µg/m^3.)
Blank	3056	PM1	10/05/2011 0:00	
Blank	3056	PM1	20/05/2011 0:00	
Blank	3056	PM1	24/05/2011 0:00	
Blank	3056	PM1	25/05/2011 0:00	
Blank	3056	PM1	27/05/2011 0:00	
Blank	3056	PM1	18/06/2011 0:00	
Blank	3056	PM1	24/06/2011 0:00	
Blank	3056	PM1	28/06/2011 0:00	
No data collected	3054	All		Filter change (31 May 2011)
No data collected	3055	All		Filter change (31 May 2011)

No data collected	3056	All		Filter change (31 May 2011)
No data collected	3054	All	29/06/2011 13:40- 29/06/2011 14:19	Filter change (30 June 2011)
No data collected	3055	All		Filter change (30 June 2011)
No data collected	3056	All		Filter change (30 June 2011)
Blank	3054	Wind direction	29/06/2011 0:00	
Blank	3055	PM1	01/07/2011 0:00	
Blank	3055	PM1	07/07/2011 0:00	
Blank	3055	PM1	11/07/2011 0:00	
Blank	3056	PM1	01/07/2011 0:00	
Blank	3056	PM1	03/07/2011 0:00	
Blank	3054	Wind direction	08/07/2011 0:00	
Blank	3054	Wind direction	11/07/2011 0:00	
Blank	3054	Wind direction	14/07/2011 0:00	
Blank	3056	PM1	13/07/2011 0:00	
Blank	3056	PM1	12/07/2011 0:00	
Blank	3056	PM1	09/07/2011 0:00	
Blank	3055	PM1	11/07/2011 0:00	
Blank	3054	Wind Direction	15/07/2011 0:00	
Blank	3054	Wind Direction	17/07/2011 0:00	
Blank	3054	Wind Direction	18/07/2011 0:00	
Blank	3055	PM1	21/07/2011 0:00	
Blank	3055	PM1	18/07/2011 0:00	
Blank	3056	PM1	19/07/2011 0:00	
Blank	3054	Wind direction	27/07/2011 0:00	
Blank	3054	Wind direction	28/07/2011 0:00	
Blank	3055	PM1	21/07/2011 0:00	
Blank	3055	PM1	24/07/2011 0:00	
Blank	3055	PM1	26/07/2011 0:00	
Blank	3055	PM1	27/07/2011 0:00	
Blank	3056	PM1	23/07/2011 0:00	
Blank	3056	PM1	24/07/2011 0:00	
Blank	3056	PM1	25/07/2011 0:00	
Blank	3056	PM1	26/07/2011 0:00	
Inserted blanks	3056	All including date	27/07/2011 23:30- 28/0702011 0:00	There is missing data and dates until the end of down load cycle
Inserted blanks	3054	All including dates and times	28/07/2011 0:10 28/07 2011 10:20	2 Lines inserted in raw data at row 12499 12500 (Filter change)
Inserted blanks	3055	All Including dates and times	28/07/2011 10:30 28/07/2011	4 Lines inserted in raw data at row 12501,

			10:40 28/07/2011 10:50 28/07/2011 11:00	12502,12503,12504 (Filter change)
Inserted blanks	3056	All Including dates and times	28/07/2011 11:10 28/07/2011 11:20	2 Lines inserted in raw data at, row 12505, 12506 (Filter change)
Blank	3054	Wind direction	31/07/2011 0:00	
Blank	3054	Wind direction	04/08/2011 0:00	
Blank	3055	PM1	01/08/2011 0:00	
Blank	3055	PM1	03/08/2011 0:00	
Blank	3056	PM1	31/07/2011 0:00	
Blank	3056	PM1	01/08/2011 0:00	
Blank	3056	PM1	03/08/2011 0:00	
Blank	3054	Wind direction	04/08/2011 0:00	
Blank	3054	Wind direction	05/08/2011 0:00	
Blank	3054	Wind direction	06/08/2011 0:00	
Blank	3054	Wind direction	10/08/2011 0:00	
Blank	3055	PM1	08/08/2011 0:00	
Blank	3055	PM1	11/08/2011 0:00	
Blank	3056	PM1	06/08/2011 0:00	
Blank	3056	PM1	10/08/2011 0:00	
Blank	3054	Wind direction	12/08/2011 0:00	
Blank	3054	Wind direction	15/08/2011 0:00	
Blank	3055	PM1	13/08/2011 0:00	
Blank	3055	PM1	14/08/2011 0:00	
Blank	3055	PM1	16/08/2011 0:00	
Blank	3055	PM1	17/08/2011 0:00	
High data point	3055	Total particles	17/08/2011 4:10	An extremely high value of 1388.6 µg/m^3 was recorded for Osiris 3055. The other OSIRIS monitors produced slightly high values during the same time period. Total Particles for OSIRIS 3054 was 456 µg/m^3 and OSIRIS 3056 was 162.3 µg/m^3.
Blank	3055	PM1	18/08/2011 0:00	
Blank	3056	PM1	14/08/2011 0:00	
Blank	3056	PM1	15/08/2011 0:00	
Blank	3056	PM1	18/08/2011 0:00	
Blank	3054	Wind direction	22/08/2011 0:00	

Blank	3055	PM1	19/08/2011 0:00	
Blank	3055	PM1	20/08/2011 0:00	
Blank	3056	PM1	21/08/2011 0:00	

*24 hours averages were removed between 26/05/2011 and 29/05/2011, due to invalid data available from OSIRIS 3054 during the inlet heater off trial.