Blue Mountains and Lithgow
Air Watch Ambient Air Quality Monitoring

Background to Study
February 2020

Participating Organisations:
Blue Mountains City Council
Blue Mountains Conservation Society
Blue Mountains Union and Community
Doctors for the Environment
Environment Protection Authority
Lithgow Environment Group
Lithgow City Council
Nepean Blue Mountains Local Health District
Department of Planning, Industry and Environment
Western Sydney University

ACCRONYMS

AM	Arithmetic Mean
AQM	Air Quality Monitoring
BMCC	Blue Mountains City Council
BMCS	Blue Mountains Conservations Society
BMUC	Blue Mountains Union and Community
CI95	95% Confidence Interval
CO	Carbon monoxide
DPIE	Department of Planning, Industry and Environment
EPA	Environment Protection Authority
GM	Geometric Mean
KOALA	Knowing Our Local Ambient Air Quality
LCC	Lithgow City Council
NBMLHD	Nepean Blue Mountains Local Health District
NEPM	National Environment Protection Measure
PM	Particulate matter
$PM_{2.5}$	Particles with a mass median aerodynamic diameter of 2.5μm
PM_{10}	Particles with a mass median aerodynamic diameter of 10 μm
ppm	Parts per million
pphm	Part per hundred million
QUT	Queensland University of Technology
WSU	Western Sydney University

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1. INTRODUCTION

The Blue Mountains and Lithgow Air Watch project is a 12-month community initiated research project supported by the NSW Environment Protection Authority (EPA) and the NSW Department of Planning, Industry and Environment (DPIE, formerly the Office of Environment and Heritage), as well as other local stakeholders.

The purpose of the project is to provide a better picture of air quality in the region and help inform future initiatives to protect air quality. This is done by gathering data across the greater Blue Mountains to observe the potential impacts of natural (bushfires, plant oils, dust storms) and anthropogenic (traffic, wood smoke, construction, industry etc.) sources on air quality in the region.

Previous air quality monitoring in the Blue Mountains and Lithgow area was in the late 1990s. The closest current NSW DPIE Air Quality Monitoring (AQM) Network stations are located in Sydney (St Marys and Richmond), after which there are no AQM stations until Bathurst, a distance of approximately 160 km.

The project was initiated by the Blue Mountains Conservation Society (BMCS), Blue Mountains Union and Community (BMUC), Doctors for the Environment and the Lithgow Environment Group, and includes representatives from the Blue Mountains City Council (BMCC), Lithgow City Council (LCC), Western Sydney University (WSU), Nepean Blue Mountains Local Health District (NBMLHD), DPIE and the EPA, which formed the Project Steering Committee.

The project includes collecting local air quality data for twelve months from May 2019 using:

- one (1) temporary compliance air quality monitoring station located at Katoomba; and

- twelve (12) low cost air quality sensors, known as KOALAs (Knowing Our Ambient Local Air-Quality), located at Katoomba, Lithgow, Springwood and Wentworth Falls (Figures 1 and 2).

The locations of the temporary compliance air quality monitoring station and the KOALAs were selected by the community representatives in the steering committee.

Figure 1: KOALA low cost air monitoring sensor (QUT)

Figure 2: Location of KOALAs, Blue Mountains and Lithgow

The KOALAs were developed by the Queensland University of Technology (QUT). They measure concentrations of particles less than of 10 microns (PM_{10}) and less than 2.5 microns ($PM_{2.5}$) in diameter, as well as carbon monoxide, in real time and data is uploaded to a dedicated website maintained by QUT (http://bluemountains.sensors.net.au/).

The compliance air quality monitoring station in Katoomba is equipped with reference instruments for monitoring the quality of air for assessment in relation to the health based air quality standards set out in the National Environment Protection (Ambient

Air Quality) Measure (AAQ NEPM). The data from the Katoomba station (Figure 3) will be used to assess baseline air quality over the 12 months, and for the validation of the KOALAs pre and post deployment to community monitoring sites.

Figure 3: Location of Katoomba Compliance Station, Air Services Australia, Valley Road

The scope of the project is to:

- Analyse PM_{10}, $PM_{2.5}$ and carbon monoxide concentrations within and between the Blue Mountains and Lithgow townships;
- Identify potential sources of air pollutants that may be impacting the Blue Mountains and Lithgow townships;
- Compare compliance station data against the health based air quality standards and establish a baseline; and
- Report and make recommendations where appropriate based on these findings.

2. METHODOLOGY

Four (4) seasonal reports will be provided during the project, culminating in a final report of the 12-month data set in 2020.

KOALAs

The KOALAs are solar powered, low cost, air quality monitors designed by the QUT's International Laboratory for Air Quality and Health (2019) (Figure 4). The units are fitted with:

- Plantower PMS1003 detector for $PM_{2.5}$ and PM_{10} particulates
- Aphasense CO-B4 gas sensor for carbon monoxide Temperature and humidity sensor.
- Data logger
- 3G sim for telemetry
- Solar panel and battery

Figure 4: KOALA fitted with Carbon Monoxide and Particulate Sensors

The particle sensors work on the principle of light scattering. Put simply, an air stream containing particles is passed through a laser beam, and the concentration of particulate matter (PM) is calculated according to the degree of light scattering. The degree of scattering is then calculated as mass measurement in micrograms per cubic metre of air ($\mu g/m^3$). The Alphasense CO-BR CO sensor is an electrochemical sensor that picks up changes in electrical charge when gas comes into contact with the detection unit. The change is then calculated as a measure of carbon monoxide in parts per million (ppm).

The KOALAs are not reference standard instruments, and the data cannot be compared directly to ambient air quality standards. They are, however, valuable tools for the detection of local air pollution sources, assessing variability within and between discrete locations, and as tools for community education and awareness around management of air quality.

Katoomba Compliance station

Ambient air quality data at the Katoomba compliance station is managed by the DPIE's Climate and Atmospheric Science Branch (ISO/IEC17025 compliant and NATA accredited 14209).

The Katoomba site is located at a latitude of 33° 42' 37"S, longitude of 150° 17' 59"E and an elevation of 1045.9 metres (DPIE 2019). Air quality parameters monitored at the station include:

- Ozone (O_3) – ultraviolet spectroscopy
- Oxides of nitrogen (NO, NO_2 and NOx) – chemluminescence
- Carbon monoxide (CO) – infrared spectrometry
- Sulfur dioxide (SO_2) - pulsed fluorescent spectrometry
- Particles less than 10 micron ($PM_{10)}$ – Tapered Element Oscillating Microbalance (TEOM)
- Particles less than 2.5 micron ($PM_{2.5)}$ - TEOM
- Visibility using nephelometry -
- Wind speed, wind direction and sigma theta
- Ambient temperature
- Relative humidity

Ambient air quality data collected at the site is compliant with Schedule 3 of the National Environment Protection (Ambient Air Quality) Measure and assessment in relation to air quality standards. Monitoring data from the Katoomba Compliance station will be compared against air quality standards over the 12-month period when the complete data set is obtained (DPIE 2019; NEPC 2019).

Table 1: Australian Standards for Air Quality

Pollutant	Averaging period	National Standard (NEPM)	NEPM (max allow exceedance)	NSW Reporting Format
Carbon monoxide	8 hours	9.0 ppm	1 day a year	9.0ppm
Nitrogen dioxide	1 hour	0.12 ppm	1 day a year	
	1 year	0.03 ppm		
Photochemical oxidants (as ozone)	1 hour	0.10 ppm	1 day a year	12.0 pphm
	4 hours	0.08 ppm	1 day a year	8.0 pphm
Sulfur dioxide	1 hour	0.20 ppm	1 day a year	20 pphm
	1 day	0.08 ppm	1 day a year	
	1 year	0.02 ppm		
Lead	1 year	0.50 µg/m^3		
Particles as PM_{10}	1 day	50 µg/m^3	5 days a year	50 µg/m^3
	1 year	25 µg/m^3		
Particles as $PM_{2.5}$	1 day	25 µg/m^3	1 day a year	25 µg/m^3
	1 year	8 µg/m^3		

(source: https://www.legislation.gov.au/Details/F2016C00215)

Background Data

Meteorological data, including rainfall, temperature, humidity, wind speed and direction is sourced, where available, from nearest Australian Bureau of Meteorology (BOM) monitor station to the KOALA clusters (www.bom.gov.au). Information on scheduled hazard reduction burns and bushfires in the surrounding area is downloaded from the NSW Rural Fire Service (https://www.rfs.nsw.gov.au/)

Data Analysis

KOALA data is downloaded and transformed into hourly averages in R version 3.5.2. The databases will be established in Microsoft Excel, and analysis undertaken in STATA Version 15.

The data from KOALAs will not be compared against the air quality standards because they do not comply with the legislated requirements for collection of data for the purpose of comparison with Australian air quality standards.

3. VALIDATION MONITORING

The KOALAs were co-located at the Katoomba Compliance Station from the 16th to 28th April 2019 for validation testing. The results of the testing indicated that the KOALAs tracked well with the Compliance Station instruments in response to shifts in air quality indicators. However, as would be expected with low cost sensors, they did not have the accuracy and precision of the reference instruments. The twelve KOALAs are labelled 61 to 72.

Particulate Monitoring

Table 1 provides a comparison of the $PM_{2.5}$ data from KOALAs with the DPIE Compliance Station tapered element oscillating microbalance (TEOM) during the two-week colocation period. The difference between the geometric means (GM) calculated for each sensor varied from -0.4 µg/m^3 (K61) to 9.3 µg/m^3 (K64) relative to TEOM, averaging 4.4 µg/m^3 across all 12 KOALAs (Table 2; Figure 5). Based on the findings from colocation, the sensor for K64 was replaced prior to deployment. The results for PM_{10} followed a similar pattern for $PM_{2.5}$ and are presented in Appendix A.

Table 2: Comparison of KOALA sensor $PM_{2.5}$ Data Versus Compliance Station, Katoomba 16-28 April 2019

Instrument Reference	Particulate Matter Less than 2.5 µm in Diameter (µg/m^3)		
	KOALA*	Compliance Station*	Difference
K61	3.8 (3.2 ; 4.5)	4.2 (3.8; 4.5)	-0.4
K62	8.6 (7.8 ; 9.5)	4.2 (3.8; 4.5)	4.4
K63	5.5 (4.9 ; 6.2)	4.2 (3.8; 4.5)	1.3
K64	13.5 (12.5; 14.5)	4.2 (3.8; 4.5)	9.3
K65	9.1 (8.3 ; 10.0)	4.2 (3.8; 4.5)	4.9
K66	10.0 (9.0 ; 11.2)	4.2 (3.8; 4.5)	5.8
K67	12.2 (11.4 ; 13.1)	4.2 (3.8; 4.5)	8.0
K68	4.8 (4.3 ; 4.5)	4.2 (3.8; 4.5)	0.6
K69	7.9 (7.2 ; 8.6)	4.2 (3.8; 4.5)	3.7
K70	10.2 (9.6 ; 10.8)	4.2 (3.8; 4.5)	6.0
K71	11.7 (11.0 ; 12.3)	4.2 (3.8; 4.5)	7.5
K72	13.1 (12.2 ; 14.1)	4.2 (3.8; 4.5)	8.9
ALL KOALAS	9.2 (8.5 ; 9.9)	4.2 (3.8 ; 4.5)	5.0

* Measurements presented are GM (95% Confidence Intervals)
#KOALA GM - Compliance TEOM GM

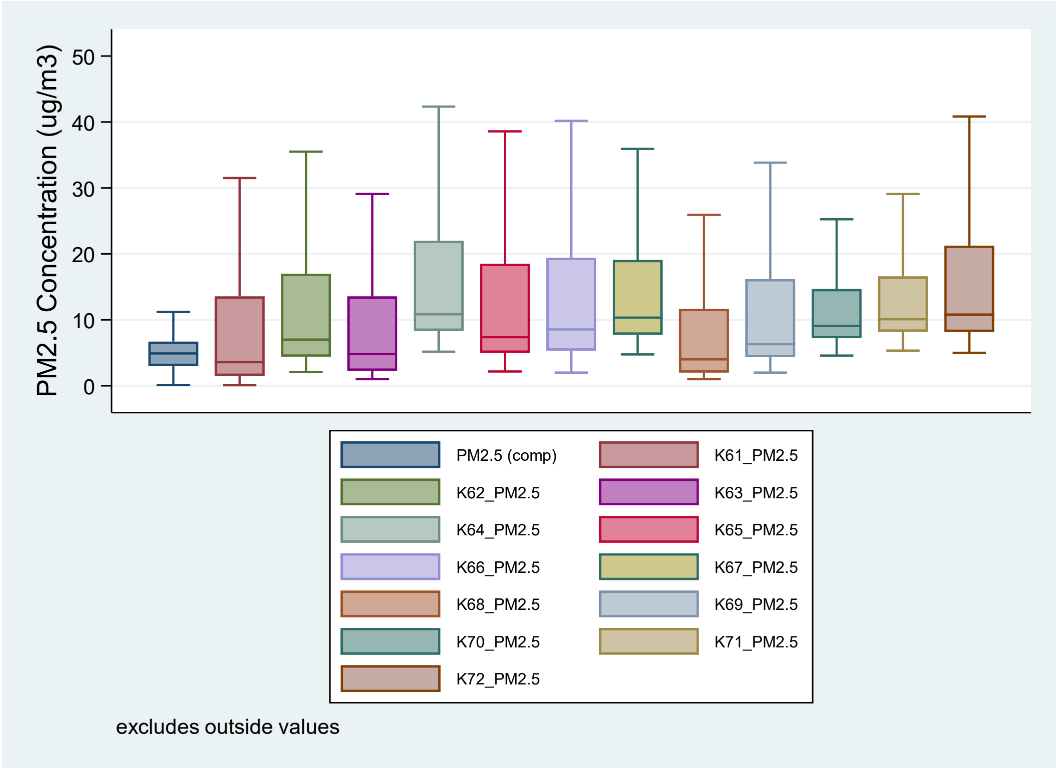

Figure 5: Comparison of $PM_{2.5}$ readings for KOALA sensors Versus Compliance Station, 16-28th April 2019

The difference between the particulate measurements by the KOALAs and TEOM is expected given the different detection mechanisms. Low cost particulate sensors that use light scatter as a detection method (photometers), such as the KOALAs, do not have the accuracy and precision of gravimetric instruments. The reduced accuracy and precision can occur for number of reasons. Firstly, low cost sensors are not fitted with heaters or dryers, and events such as fog or haze may result in the overestimation of particulate levels due to fine droplets registering as particles. The sensors may also be influenced by differences in the physicochemical properties of aerosol sampled versus the test dust used to calibrate the sensor, as well as non-linearity of sensor response in the presence of high particulate concentrations (Chung et al. 2001; Grimm & Eatough 2009; Jayaratne et al. 2018; Kelly et al. 2017; Sousan et al. 2016).

The potential effect of moisture (humidity) on the sensors was observed during the colocation period; KOALA $PM_{2.5}$ and PM_{10} displaying a moderate correlation with humidity levels of Rs=0.680 and PM_{10} Rs=0.709 respectively, while TEOM $PM_{2.5}$ did not correlate with humidity (Rs=0.141) (Figure 6).

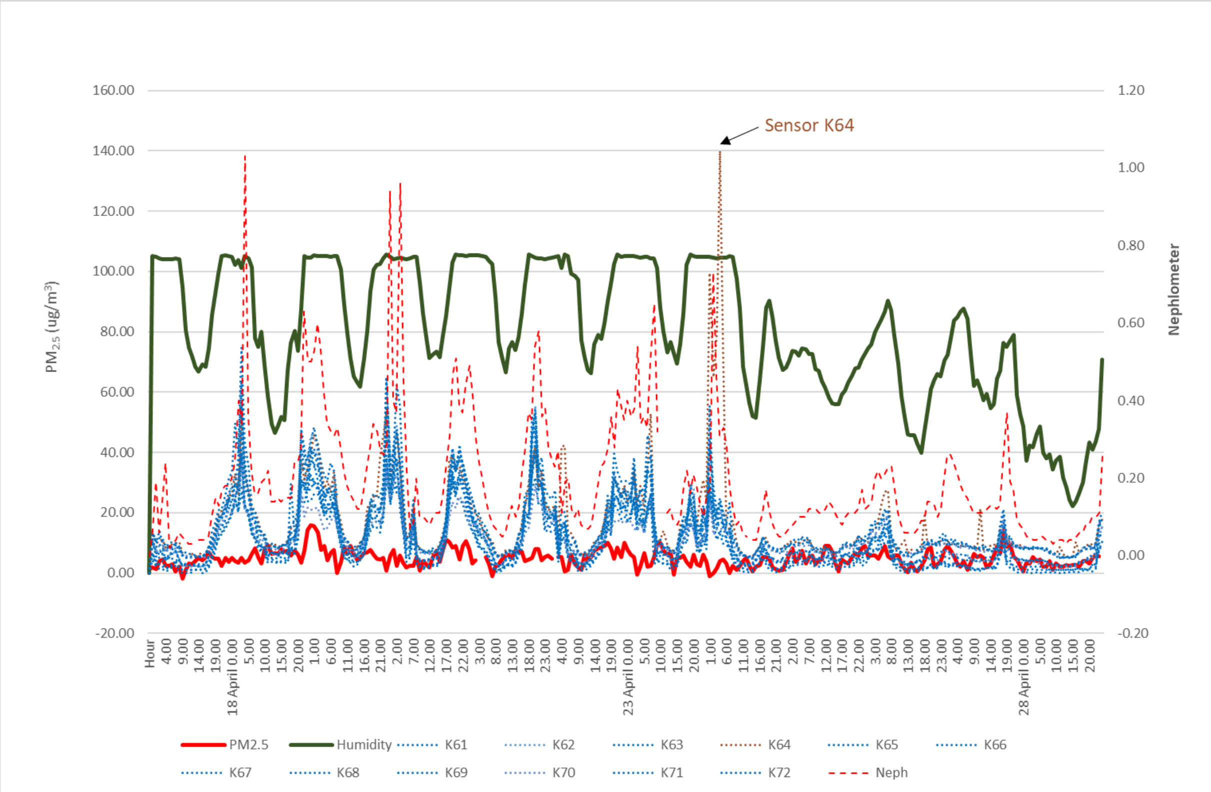

Figure 6: Comparison of Real-Time $PM_{2.5}$ Measurement by KOALAs Versus Compliance Station, 16th-28th April 2019

Carbon monoxide

The ambient carbon monoxide levels in Katoomba during the colocation period were at the limits of detection for both the KOALAs and Compliance Station, typically less than 100 ppb (0.100 ppm). The carbon monoxide sensors trended well between each of the KOALAs, with the exception of K62 and K70 that were adjusted prior to deployment (Figure 7).

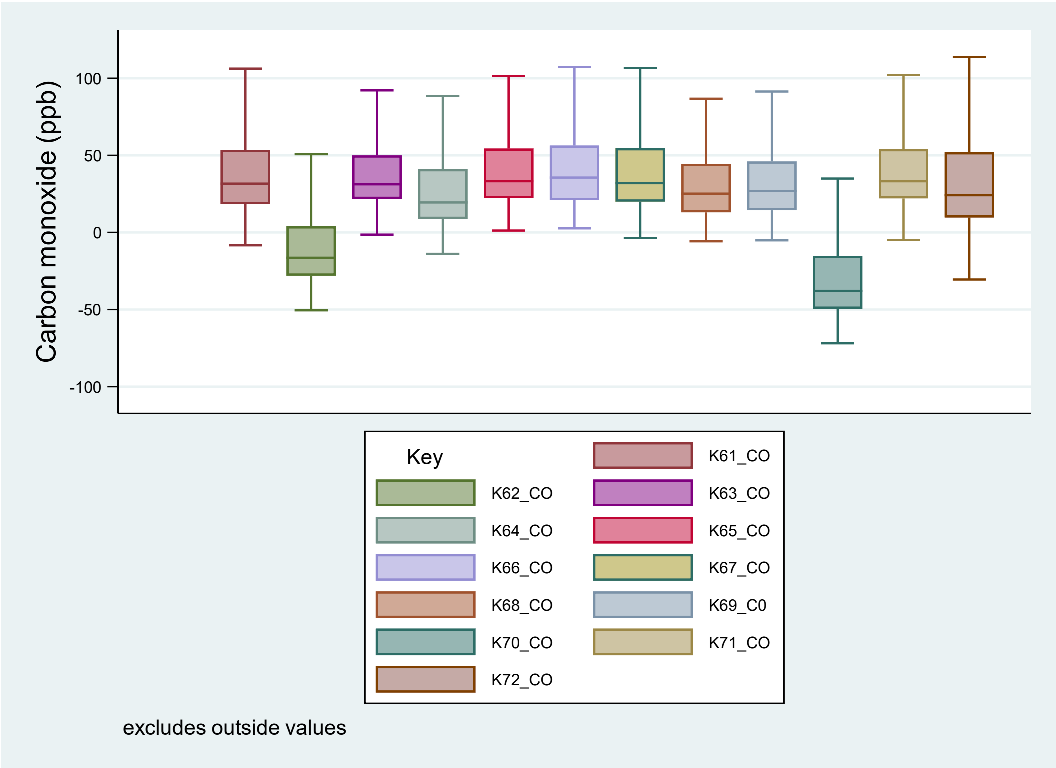

Figure 7: Comparison of Carbon Monoxide (ppb) readings for KOALAs 16-28th April 2019

4. VALIDATION FINDINGS

Although there are limitations in the use of low cost sensors for studying ambient air quality, these sensors offer a more affordable option, enabling community studies that may not otherwise be possible using the more expensive reference standard instruments.

In the case of this project, the data from the pre and post colocation period informs of potential differences both between the KOALAs, as well as between individual KOALAs over the duration of the project. These issues may include sensor drift, non-linearity for very high concentrations of particulate matter or carbon monoxide, and influence of humidity, fine mists and vapours.

5. REFERENCES

DPIE, 2019. ‘How we monitor air pollution’, available from; https://www.environment.nsw.gov.au/topics/air/monitoring-air-quality

Chung, A, Chang, DPY, Kleeman, MJ, Perry, KD, Cahill, TA, Dutcher, D, McDougall, EM & Stroud, K 2001, 'Comparison of Real-Time Instruments Used To Monitor Airborne Particulate Matter', *Journal of the Air & Waste Management Association*, vol. 51, no. 1, pp. 109-20.

DPIE 2019, *Air quality monitoring network*, Department of Planning Industry and Envrionment,, viewed 10 November 2019, <https://www.environment.nsw.gov.au/topics/air/monitoring-air-quality>.

Grimm, H & Eatough, DJJJotA 2009, 'Aerosol measurement: the use of optical light scattering for the determination of particulate size distribution, and particulate mass, including the semi-volatile fraction', *Journal of the Air Waste Management Association*, vol. 59, no. 1, pp. 101-7.

Jayaratne, R, Liu, X, Thai, P, Dunbabin, M & Morawska, LJAMT 2018, 'The influence of humidity on the performance of a low-cost air particle mass sensor and the effect of atmospheric fog', vol. 11, no. 8, pp. 4883-90.

Kelly, K, Whitaker, J, Petty, A, Widmer, C, Dybwad, A, Sleeth, D, Martin, R & Butterfield, AJEP 2017, 'Ambient and laboratory evaluation of a low-cost particulate matter sensor', vol. 221, pp. 491-500.

NEPC 2019, *National Environment Protection Measures (NEPMs)*, Australian Government,, viewed 10 October 2019, <http://www.nepc.gov.au/nepms>.

Sousan, S, Koehler, K, Thomas, G, Park, JH, Hillman, M, Halterman, A, Peters, TMJAS & Technology 2016, 'Inter-comparison of low-cost sensors for measuring the mass concentration of occupational aerosols', vol. 50, no. 5, pp. 462-73.

Appendix A: **Colocation Results for Particulate Matter**

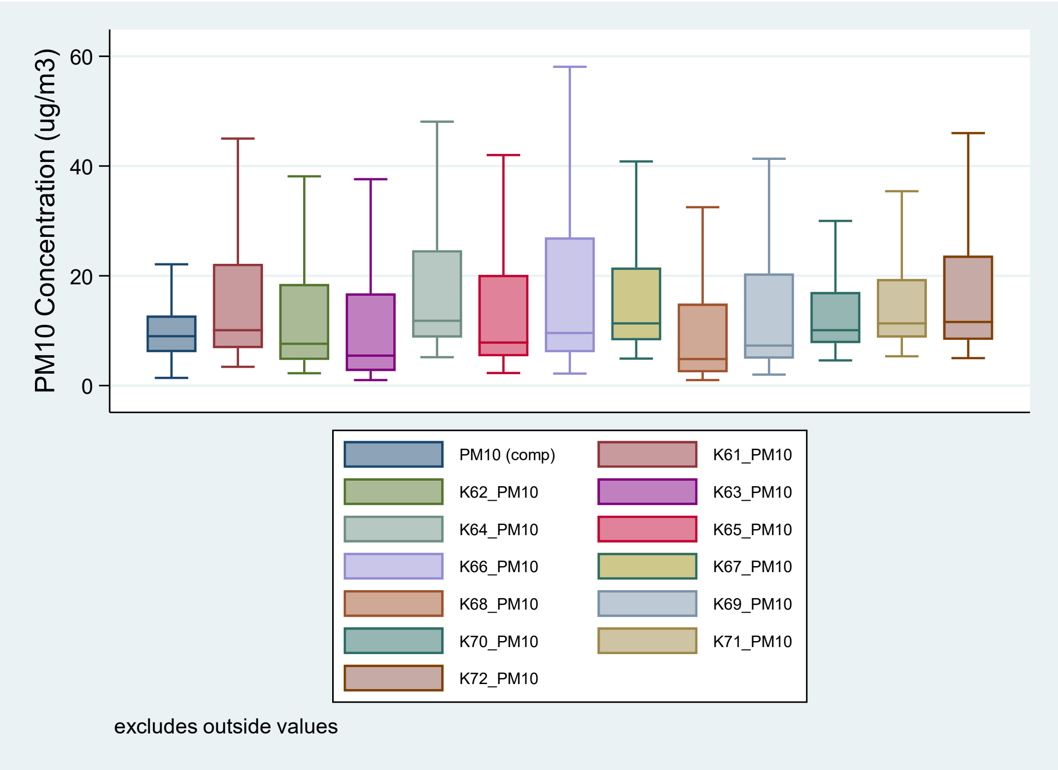

Figure A1: Comparison of PM_{10} readings for KOALA sensors Versus Compliance Station, 16-28th April 2019

Table A1: Comparison of PM_{10} Measurements by KOALA sensors with Compliance Station TEOM, 16th to 28th April 2019

Instrument Reference	Particulate Matter Less than 10μm in Diameter (μg/m^3)		
	KOALA*	Compliance Station*	Difference
K61	12.4 (11.4-13.6)	8.6 (8.0-9.3)	3.8
K62	9.4 (8.5-10.5)		0.8
K63	6.4 (5.7- 7.3)		-2.2
K64	14.8 (13.7- 16.0)		6.2
K65	10.1 (9.2 – 11.2)		1.5
K66	12.2 (10.9- 13.7)		3.6
K67	13.7 (12.7-14.8)		5.1
K68	5.8 (5.1 – 6.5)		-2.8
K69	9.2 (8.4-10.1)		0.6
K70	11.5 (10.8-12.2)		2.9
K71	13.2 (12.4-14.0)		4.6
K72	14.0 (13.0 – 15.2)		5.4
ALL KOALAS	10.6 (10.3-11.0)		2.5

* Measurements presented are GM (95% Confidence Intervals)
#KOALA GM - Compliance TEOM GM