GLA

AIR FILTRATION IN LONDON SCHOOLS

Final Report

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EXECUTIVE SUMMARY

- WSP installed air filtration systems and monitoring devices into 5 schools across London on behalf of the Greater London Authority (GLA), as part of the Mayor's School Filters Programme. Within all school installations, continuous monitoring of $PM_{2.5}$ was undertaken alongside the Air Filtration Systems (AFSs), and at a control classroom where no AFS was installed. $PM_{2.5}$ monitoring data results indicate that all filtration systems appear to be effective at reducing $PM_{2.5}$ concentrations within classrooms, with the larger commercial AFS having the most significant impact on reducing $PM_{2.5}$ concentrations, with up to a 68.39% difference in $PM_{2.5}$ concentrations. This compares with a maximum reduction of 50.8% difference in $PM_{2.5}$ concentrations for the medium commercial AFS, and a maximum reduction of 0.04% in $PM_{2.5}$ concentrations for the DIY AFS (however, the DIY AFS system had limited use). There was a single instance at Hampden Gurney where $PM_{2.5}$ reduction by the larger commercial air filtration system was less effective, though this could have been due to interference with the air filtration system and higher background levels of pollution. Performance of filtration systems were subject to immediate environmental factors such as open windows or classroom doors for ventilation. Filtration performance appeared to be less effective when installed on floors other than ground floor, as was the case at Hampden Gurney and Sacred Heart Primary schools. All manufactured air filtration systems were very well received by school staff and appeared to cause no disruption to the operation of classrooms and classroom activities. However, the installation of the DIY AFS was not generally well received, due its size and safety concerns. In one case, a classroom teacher and school manager decided to remove it from the classroom, as it was not considered appropriate to deploy within a classroom setting.

- Findings from this research highlighted several suggestions for future rollout. Firstly, the clean air delivery rate of the selected air AFSs should be appropriate for the classroom size to be filtered. Locations for positioning the air filtration system should avoid any dilution of the air filtration system effectiveness, by avoiding locating too close to open windows or doors. The effectiveness of air filtration systems appeared to less in classrooms on first and second floors compared to classrooms on ground floors where intrusion of outdoor pollution is likely to be higher, however, due to the limited nature of this study no firm conclusions can yet be drawn, and should be explored further with more monitoring and comparison. A final learning is that it is important that classroom staff have control over the air flow rate to increase staff autonomy over noise and temperature.

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1 INTRODUCTION

1.1 CONTEXT OF THE NEED FOR THIS STUDY

The Mayor of London is committed to reducing the impact of poor air quality in London. Road transport is a key contributor towards poor air quality, and whilst transport in London is getting cleaner through bold initiatives like the London-wide ULEZ, poor air quality around busy streets and interchanges will continue to pose challenges in the immediate term. In addition, non-transport sources, such as domestic wood burning and Non-Road Mobile Machinery remain a significant contributor to air pollution across London.

AIR QUALITY AND INDOOR AIR QUALITY IN THE UK

Estimates of the mortality burden of long-term exposure to outdoor air pollution in England in 2019 was estimated to be equivalent to 26,000 to 38,000 deaths a year[1].

The Chief Medical Officer's Annual Report on Air Pollution[2] has highlighted the importance of indoor air pollution, with adults spending over 80% their day indoors, and school children likely to be similar. Current understanding of sources and exposure to indoor air quality is much less developed than understanding of the sources and exposure surrounding ambient air quality. Attention is being drawn towards indoor air quality for several reasons:

- Ambient air quality is improving, so focus is shifting to include indoor air quality
- An indirect outcome of improving building energy efficiency is a reduction in natural ventilation
- Our understanding of the link between indoor air pollutants and health is improving
- Low-cost sensors have provided greater opportunity for monitoring indoor air quality.

It is understood that reducing both indoor and outdoor emissions of toxic pollutants will lead to the largest improvements in indoor air quality, however it is noted many of the sources in the indoor environment cannot be reduced. As such, mitigations such as ventilation and

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[1] Mitsakou C et al. Updated mortality burden estimates attributable to air pollution. In UK Health Security Agency. Chemical hazards and poisons report; Issue 28. Reducing health harms associated with air pollution; 2022. [Accessed 14 September 2022]. Available from: https://www.gov.uk/government/collections/chemical-hazards-and-poisons-reports.

[2] Chief Medical Officer's annual report 2022: air pollution - GOV.UK (www.gov.uk)

filtration of indoor air play a key role in reducing unavoidable indoor air pollution. This report explores the effectiveness and practicalities of air filtration within several primary schools in London.

There is limited information about typical indoor exposure to pollutants and its associated health effects, mainly due to the challenges of conducting large-scale monitoring or exposure assessment studies in people's homes. In addition, indoor environments are highly variable, and emissions can vary vastly between similar indoor environments occupied by differing individuals.

Children are known to be particularly susceptible to the health effects of air pollution, as their lungs and other organs are still developing, and they inhale at a higher rate per body weight than adults[3]. Air quality is also an equalities issue. Children who are exposed to higher levels of pollution are more likely to experience socio-economic inequalities which are worsened by pollution.

The 2005 WHO guideline level for $PM_{2.5}$ was reduced to an annual mean concentration of 5 $\mu g/m^3$ in 2021, this brought a significant number of schools in London to above the WHO $PM_{2.5}$ guideline, and schools in areas with high $PM_{2.5}$ tend to be more ethnically diverse and are generally in areas with higher levels of deprivation[4].

The Mayor is committed to achieving the interim WHO annual average guideline for $PM_{2.5}$ of $10\mu g/m^3$ by 2030, and achieving the final WHO guidelines as soon as possible to protect the health of Londoners.

1.2 OBJECTIVES OF THIS RESEARCH

In assisting the GLA to improve indoor air quality in London schools, WSP has worked with the GLA in deploying a research project as part of the Mayor's Schools Filter Programme. This included use of both DIY filters and off-the-shelf filters with stand-alone sensors

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[3] World Health Organization (WHO). Children and Air Pollution 2022. [Accessed 4 October 2022]. Available from: https://www.who.int/news-room/spotlight/how-air-pollution-is-destroying-our-health/children-and-air-pollution.

[4] Osborne S et al. Air quality around schools: Part II – Mapping $PM_{2.5}$ concentrations and inequality analysis. Environmental Research. 2021;197:111038. [Accessed 4 October 2022]. Available from: https://doi.org/10.1016/j.envres.2021.111038.

installed separately to measure filtration unit performance.

The Mayor’s School Filters programme builds on existing work to tackle air quality in and around London’s schools. This includes the school and nursery audits, which WSP supported, which identified effective measures which could reduce the impact of pollution on the health of pupils.

The aim of this study was to test some Air Filtration Systems (AFSs) to see if they would be practical for wider roll out across London classrooms. As part of the performance testing, WSP deployed approved and certified monitoring methods providing high quality data and evidence to robustly determine the best filtration technique and deployment approach. All the AFSs deployed were mains electrically powered air purifier units, which used filtration as the main component.

2 METHODOLOGY

2.1 OVERVIEW OF METHODOLOGY

WSP have structured its methodology in order that the outputs aim to answer the following questions:

- Is there a measurable exposure reduction from use of filtration units in school classrooms?
- How can we ensure the approach is proactive in relation to equalities, diversity and inclusion?
- How will filters be installed across a range of classrooms, schools and boroughs?
- How will we go about managing all communications and logistics directly with the schools?
- How will our approach provide value for money, minimising on-going costs?
- How will health and safety, liability and risk be assessed, dealt with, with full DBS checks for all staff working in schools?

The approach has been designed to embrace innovation, be inclusive, robust, evidence-based, inherently safe and add value. A similar methodology was undertaken by WSP on behalf of the GLA in a study investigating the effectiveness of AFSs in nurseries, with the main differences in this project being: it looks exclusively at $PM_{2.5}$; involvement of primary schools; refinements to communications with schools and reporting based on lessons learnt from the nursery school AFS trials. This study also solely investigated AFSs, whereas the nursery study investigated use of air purifiers which included filtration with additional purifier technologies, such as ionisation.

WSP successfully engaged five schools who agreed to participate with the research.

WSP only deployed DBS-checked site staff and ensured 12 months of liability coverage is in place for all AFSs installed in classrooms.

2.2 COMMISSIONING FILTRATION SYSTEMS

WSP's approach to equipment selection and installation prioritised safety, quality of filtration, instrument noise and availability of technical support and consumables/ spare parts. From previous AFS installations undertaken within nursery school classrooms on behalf of the GLA, WSP were aware of the severe constraints of introducing new electrical (potentially noisy) equipment into a classroom, due to the shortage of space within classrooms, vulnerability of primary school children and the dynamic and congested nature of a primary school classroom.

2.2.1. SELECTED AIR FILTRATION SYSTEMS

Using the above criteria, we selected one medium size and one smaller commercial AFS as well as a larger commercial HEPA-based AFS.

The DIY AFS was following a design which was considered to be effective in terms of filtration performance and well-documented. This version of the DIY AFS box fan was wood framed to ensure robustness and rigour should it be subjected to collision within the classroom setting.

All three commercial AFSs selected were considered to have a low impact on classroom noise and be unobtrusive on classroom activities.

WSP simultaneously installed the three commercial AFSs and the DIY AFS with a standalone monitoring device monitoring indoor air quality within each school. Each school received a mix of AFS, based on practicality and availability. These were positioned in adjacent classrooms to ensure similar local environments. A separate classroom was used as a sample ‘control’ to monitor non-filtered indoor air quality and acted as an air quality baseline or comparative classroom, which the performance of the AFSs were assessed.

The small commercial AFS was installed to test its acceptance as suitable for classrooms, but not allocated a monitoring device, as the remaining AFSs had higher clean air delivery rate (how much air an air-filtration system can filter and deliver in an amount of time).

2.2.2. DESCRIPTION AND PERFORMANCE CRITERIA OF THE SELECTED AIR FILTRATION SYSTEMS

A summary of each selected AFS is set out below.

<u>Smaller commercial AFS:</u> The smaller commercial AFS was reasonably modest in size and able to be positioned within the classroom to avoid representing an obstruction. Its clean air delivery rate was considerably lower than any of the other systems, and its noise level at maximum was higher than either the medium commercial AFS or the larger commercial AFS.

Medium commercial AFS: The medium commercial AFS was modest in size and able to be positioned within the classroom to avoid representing an obstruction. Its clean air delivery rate at maximum was in the order of the larger commercial filtration system at maximum, however its noise level at that performance rate was considered intrusive to classroom ambience. Lower settings were not considered intrusive.

Larger commercial AFS: The larger commercial AFS was significantly larger in size than the other three, though as it was slim (330mm depth) was able to be manoeuvred close to the classroom wall, and generally did not represent an obstruction. Its clean air delivery rate was high, without creating noise considered to be intrusive to classroom ambient in this study.

DIY AFS: The DIY AFS was the system with the greatest potential to represent a classroom obstruction, as it was square in its construction. The fabric of the DIY AFS was less robust that any of the manufactured AFSs, and likely to suffer damage through collision or through relocation. The potential clean air delivery rate of the DIY AFS was potentially very high, however, the DIY AFS suffers from air leakages after a short while due to its fabrication and used a less effective filtering system. The noise level of the DIY AFS was considered to be intrusive to classroom ambience at all but the very lowest fan rate, which reduced its potential clean air delivery rate.

The performance criteria for each AFS are set out in **Table 2-1** below:

Table 2-1 – Performance Criteria of each Air Filtration Systems selected

Filtration System	Estimated Room coverage (m2)	Power consumption (Watts)	Noise Level (dBA)	Dimensions (mm)	Weight (kg)
Smaller commercial AFS	Maximum - 73	Min 2.9 Max 35	20 - 52	165 x 340 x 469	5.5
Medium commercial AFS	Maximum - 120	5 – 90	28 - 55	415 x 245 x 600	8.5
Larger commercial AFS	Maximum - 130	48-118	29 - 43	575 × 330 × 1230	38

DIY AFS	110 (assuming a room height of 3.85m)	110	Max 60	550 x 550x 550	10

2.3 INDOOR AIR QUALITY MONITORING DEVICE

WSP deployed Airly monitors to record $PM_{2.5}$ concentrations to understand the effectiveness of the AFSs. Airlys are low cost, MCERTS[5] approved and able to instantly communicate with the data dashboard once successfully installed, and a low noise continuous device which is essential for the classrooms to be investigated.

A second set of low-cost air quality sensors were deployed, Air Gradients, at three of the five schools to serve as a back-up monitoring device.

The two monitoring devices had differing performance criteria, with the Air Gradient device able to achieve a particulate matter accuracy of ±10$\mu g/m^3$ whilst the Airly device is able to achieve a much lower particulate matter accuracy of ±1$\mu g/m^3$. These two differing instrument performance criteria will result in some differences in the absolute $PM_{2.5}$ concentrations recorded by the instruments.

[5] Monitoring emissions to air, land and water (MCERTS) - GOV.UK (www.gov.uk)

3 SCHOOL FILTRATION INSTALLATIONS

3.1 SCHOOL INSTALLATIONS

Five London primary schools successfully had filtration and monitoring equipment installed and $PM_{2.5}$ concentration data recorded. Information on these schools is contained below. Site photos illustrating an example of the site installation can be seen in **Appendix A**.

3.2 SCHOOL INSTALLATION DETAILS

Installations of filtration and monitoring equipment was undertaken at Less Ness Heath Primary School, Belverdere, Bexley; Old Bexley Church of England Primary School, Belvedere, Bexley; Sandhurst Primary School, Lewisham; Sacred Heart Primary School, Whetstone, Barnet and Hampden Gurney Primary School, Westminster. Monitoring at these schools begun on 26th April was completed on 22nd July 2024.

<u>Less Ness Primary School, Erith Road, Belvedere, Bexley, Kent, DA17 6HB</u>

Date Installed: From 26th April 2024 to 23rd May 2024

Table 3-1 - Less Ness Heath Primary School Filter Installation

Classroom	Filtration	Monitoring	Comments
1	Control	Airly 3 (0014 2472) Air Gradient GLA2	Ground floor classroom no air gradient due to poor data connection
2	Medium commercial AFS	Airly 4 (0014 0828) Air Gradient GLA1	Ground floor classroom
3	Larger commercial AFS	Airly 2 (2250) Air Gradient GLA3	Ground floor classroom
4	DIY AFS	Airly 1 (0014 386)	Ground floor classroom

<u>Old Bexley Church of England Primary School Hurst Road, Bexley, Kent, DA5 3JR</u>

Date Installed: From 10th May 2024 to 3rd July 2024

Table 3-2 - Old Bexley Church of England Primary School Filter Installation

Classroom	Filtration	Monitoring	Comments
1	Control	Airly 14229	Ground floor classroom

2	Medium commercial AFS	Airly 14214	Moved to Classroom 2 after DIY AFS removed Ground floor classroom
3	Larger commercial AFS	Airly 14079	Ground floor classroom
4	DIY AFS	DIY AFS removed due to school safety concerns.	DIY AFS removed due to school safety concerns. Ground floor classroom

Sandhurst Primary School, Minard Road, Catford, SE6 1NW

Date Installed: From 24th May 2024 to 11th July 2024

Table 3-3 - Sandhurst Primary School Filter Installation

Classroom	Filtration	Monitoring	Comments
1	Control	Airly 14225 Air Gradient GLA 1	Ground floor classroom
2	Medium commercial AFS	Airly 14247 Air Gradient GLA 3	Ground floor classroom
3	Larger commercial AFS	Airly 14079 Air Gradient GLA 2	Ground floor classroom
4	DIY AFS	Airly 14082	DIY AFS moved to spare classroom as it was considered too large and noisy for typical classroom. Spare classroom rarely used. 1st Floor Classroom

Sacred Heart Catholic Primary School, 2 Oakleigh Park South, Whetstone, London, N20 9JU

Date Installed: From 4th July 2024 to 23rd July 2024

Table 3-4 - Sacred Heart Catholic Primary School Filter Installation

Classroom	Filtration	Monitoring	Comments
1	Control	Airly 14079	1st Floor Classroom

2	Medium commercial AFS	Airly 14214	1st Floor Classroom
3	Larger commercial AFS	Airly 14229	1st Floor Classroom

Hampden Gurney Primary School, 13 Nutford Place, London, W1H 5HA

Date Installed: From 12th July 2024 to 23rd July 2024

Table 3-5 - Hampden Gurney Primary School Filter Installation

Classroom	Filtration	Monitoring	Comments
1	Control	Airly 14229	1st Floor Classroom
2	Medium commercial AFS	Airly 14214	1st Floor Classroom
3	Larger commercial AFS	Airly 14079	1st Floor Classroom

3.3 OPINIONS, COMMENTS AND INFORMATION RECEIVED FROM SCHOOL STAFF DURING INSTALLATIONS

Feedback from the schools on the AFSs installations were that the manufactured AFSs were low noise, did not interfere with classroom activities or cause any obstructions. Upon decommissioning of the AFSs there were no negative comments or observations from school staff, management or school leaders who complemented the presence of the manufactured AFSs.

Information gathered during installation and during follow-up communications with the schools suggested that in the three schools where they were deployed, the DIY AFS was unpopular. This was partly due safety concerns, size and some reports of excessive noise. During installation WSP site staff made it clear to school staff that the DIY AFS could be switched off or removed should there be any safety concerns or interference with classroom activities/ ambience.

The only device removed was the DIY AFS from Old Bexley Church of England Primary school due to safety concerns. After initial discussions with school staff during installation, the DIY AFS was not deployed in either Sacred Heart Primary School, or in Hampden Gurney Primary School.

4 RESULTS

4.1 PRESENTATION OF MONITORING RESULTS

The performance of each of the AFSs has been expressed as a percentage in terms of $PM_{2.5}$ concentration difference between the classroom with one of the AFSs (candidate classroom) and a classroom in the same school without an AFS (control classroom). For this, $PM_{2.5}$ concentration monitoring data from both a candidate classroom and the control classroom, was applied into **Equation 4-1**:

$$\boldsymbol{Equation}\ 4-1\ -\ \boldsymbol{PM2.5\ Concentration\ Difference\ Calculation}$$

$$Difference = 100\% \times |V1 - V2| / \left[\frac{V1 + V2}{2}\right]$$

V1 – $PM_{2.5}$ concentration in Control Classroom

V2 - $PM_{2.5}$ concentration in Candidate Filter Classroom

$PM_{2.5}$ concentration data was analysed for mid-week school hours only, as these were the periods when pupils and staff were exposed to $PM_{2.5}$.

$PM_{2.5}$ concentration data has been displayed for all classrooms within 'Box and Whisker' plots, these have distributed $PM_{2.5}$ concentration data into quartiles (lower quartiles as bottom line of box, and upper quartiles as top line of box), with the median $PM_{2.5}$ concentration expressed as a horizontal line within the box. The upper and lower $PM_{2.5}$ concentration outliers are expressed as two vertical lines called "whiskers", and indicate variability outside the upper and lower quartiles. Boxplots of $PM_{2.5}$ concentration monitoring data from each monitored classroom have been prepared and are analysed adjacent to other classroom data including the control (no air filtration) classroom.

Monitoring data for both Airlys and Air Gradients were screened in order to ensure only simultaneous monitoring data was analysed. This required data to be available at all of the same monitoring devices within each school, ensuring data intercomparison were consistent. Where data was available at one or two monitoring devices, and not the third or fourth, then all data was screened out.

4.2 LESS NESS HEATH PRIMARY SCHOOL MONITORING DATA

AIRLY MONITORING DATA

Airly concentration data has been gathered for all classrooms monitored at Less Ness Heath Primary School. A series of plots have been undertaken using the open-source analytical tool 'OpenAir'. These include time series, diurnal variation, monthly averages and daily averages for all classrooms monitored (**Figure 4-1**).

Figure 4-1 - Summary Airly $PM_{2.5}$ concentrations across the filtered and Control classrooms Less Ness Heath Primary School 26/04/2024 - 23/05/2024

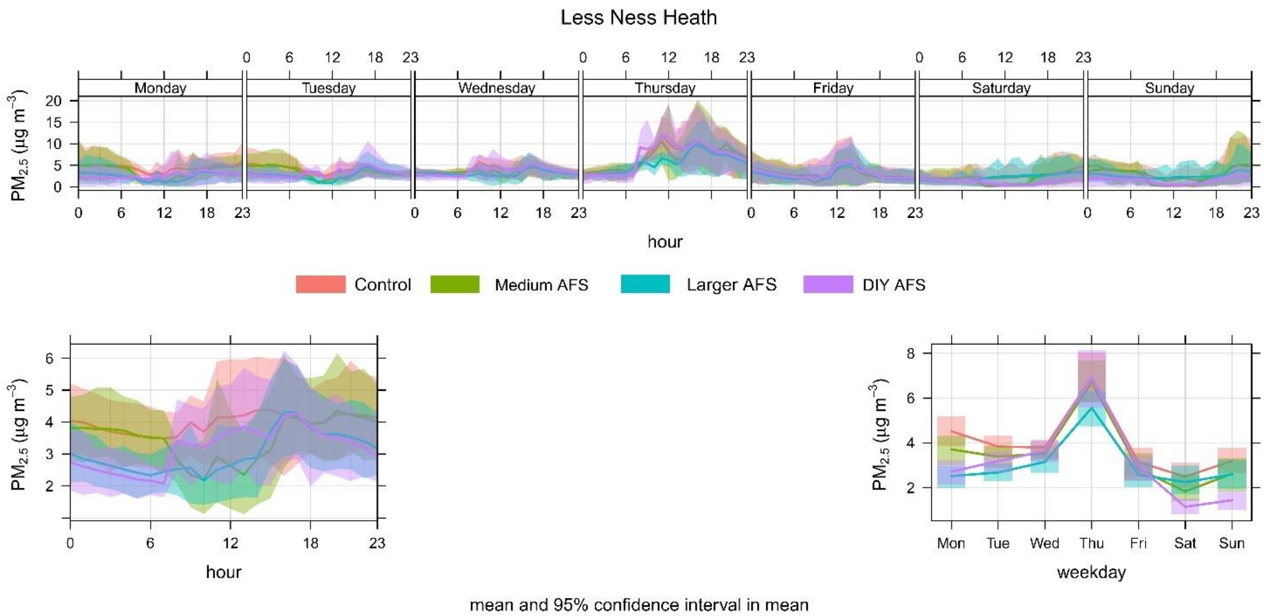
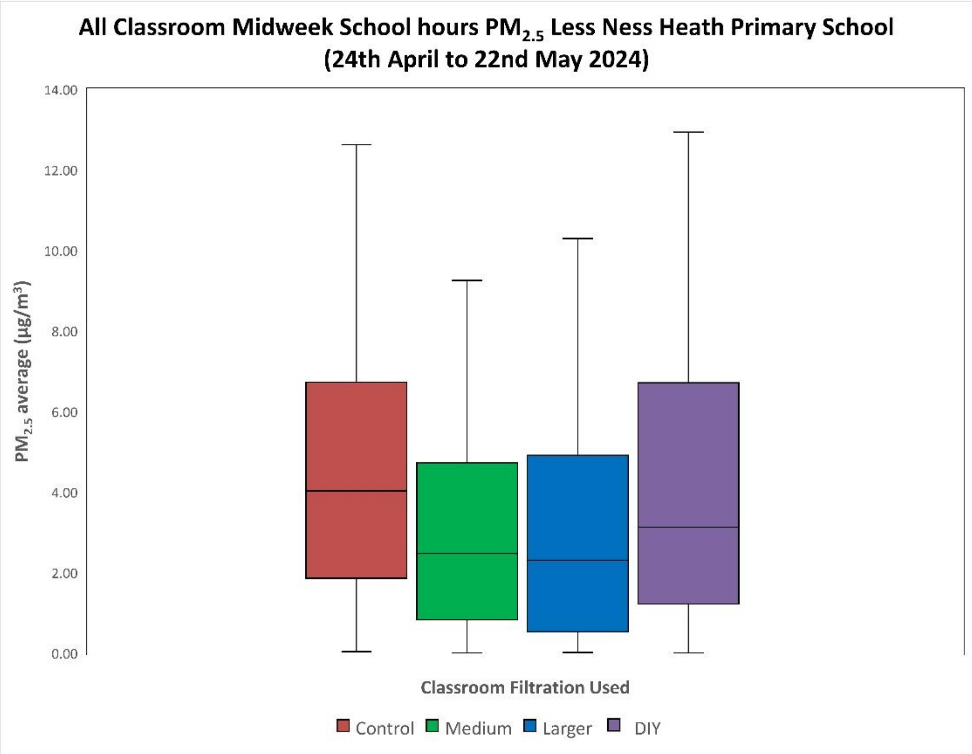


Figure 4-2 – $PM_{2.5}$ Concentration Less Ness Heath Primary School – Airly Monitoring Data



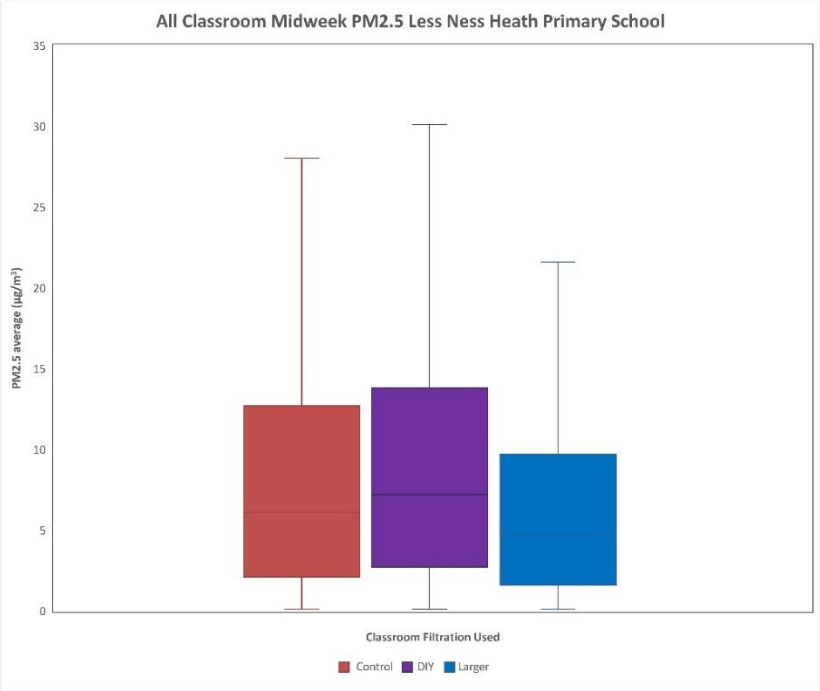
It can be seen from the $PM_{2.5}$ concentration data from Less Ness Heath Primary School in **Figure 4-2** above, that median concentrations (middle line in each box) within the larger commercial AFS classroom appears to be lower than the control and the DIY classrooms over the averaged period, and slightly lower than the medium commercial AFS classroom median. The control classroom appears to be experiencing higher $PM_{2.5}$ concentrations within the diurnal variation plots and weekday average plots in **Figure 4-2**. The DIY classroom indicated lower median $PM_{2.5}$ concentrations than the control. $PM_{2.5}$ concentration differences between the larger commercial AFS classroom and the control classroom can be seen as up to 2.0 $\mu g/m^3$ higher in terms of the median $PM_{2.5}$ concentrations.

AIR GRADIENT MONITORING DATA

$PM_{2.5}$ concentration monitoring data from the Air Gradient at Less Ness School can be seen in **Figure 4-3** below. Once again concentrations were observed to be lower within the larger commercial AFS classroom than detected in the other filtered and control classrooms. $PM_{2.5}$

concentration differences between the larger AFS classroom and the control classroom can be seen as up to 2.0 $\mu g/m^3$ higher in terms of the median $PM_{2.5}$ concentrations.

Figure 4-3 – $PM_{2.5}$ Concentration Less Ness Heath Primary School – Air Gradient Monitoring



LESS NESS HEATH PRIMARY SCHOOL MONITORING DATA SUMMARY

$PM_{2.5}$ average and concentration differences between control classrooms and filtered classrooms for school hours (8:00 – 16:00, Monday to Friday) only are outlined in **Table 4-1** below.

It can be seen that the DIY AFS did not appear to reduce $PM_{2.5}$ concentrations in relation to the control classroom. With Air Gradient monitoring data indicating that $PM_{2.5}$ concentrations in the DIY classroom being slightly more elevated than within the control classroom.

Table 4-1 – $PM_{2.5}$ Concentration Differences between Control and Filtered Classrooms Less Ness Heath Primary School during school hours only

Air Filtration	Airly		Air Gradient	
	$PM_{2.5}$ Average ($\mu g/m^3$)	Concentration Differences between Control	$PM_{2.5}$ Average ($\mu g/m^3$)	Concentration Differences between Control
Control	4.57	-	7.82	-
Medium commercial AFS	3.51	-26.28%	-	-
DIY AFS	4.57	-0.04%	8.46	7.94%
Larger commercial AFS	3.11	-38.16%	5.92	-27.59%

4.3 OLD BEXLEY CHURCH OF ENGLAND PRIMARY SCHOOL MONITORING DATA

AIRLY MONITORING DATA

Airly concentration data has been gathered for two of the three classrooms monitored at Old Bexley Church of England Primary School. During monitoring, one of the Airly devices (DIY monitor) had disconnected from its data feed. A series of plots have been undertaken using the open-source analytical tool ‘OpenAir’. These include time series, diurnal variation, monthly averages and daily averages for all classrooms monitored (**Figure 4-4**).

Figure 4-4 – Summary Airly $PM_{2.5}$ concentrations across the filtered and Control classrooms Old Bexley Church of England Primary School 28/05 - 28/06/2024

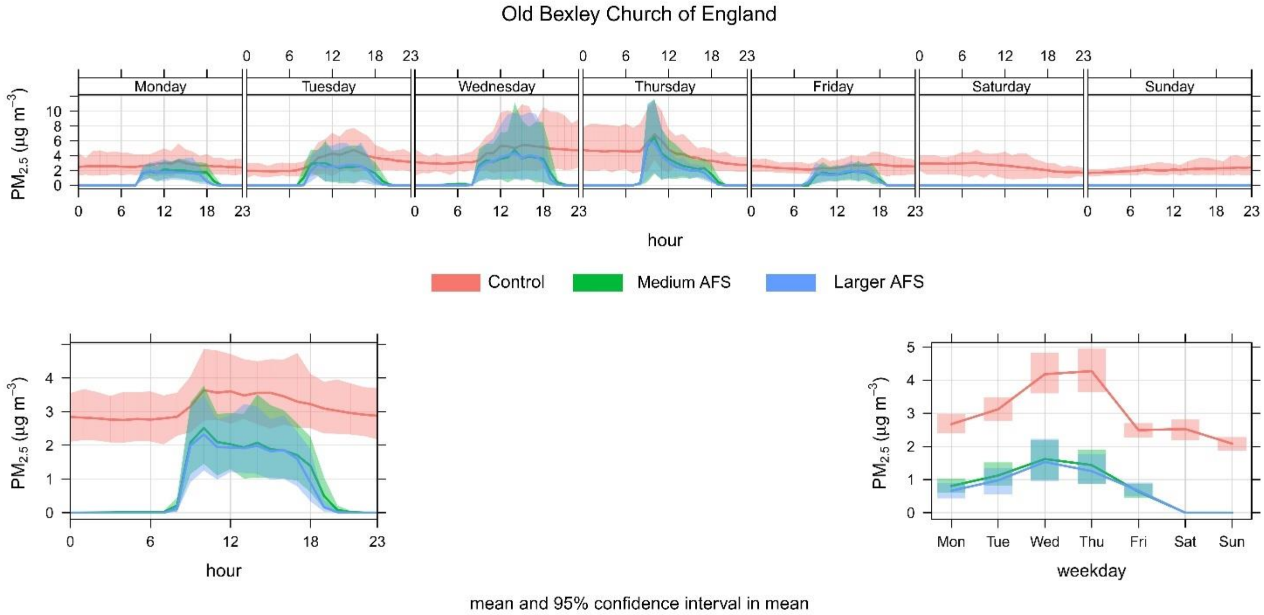
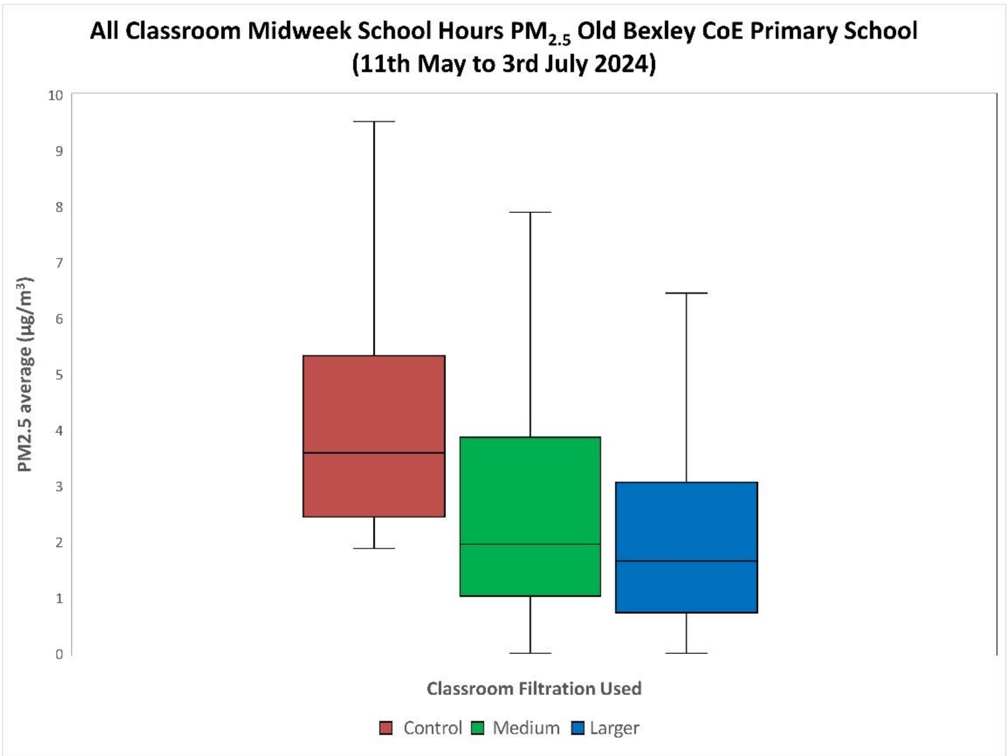


Figure 4-5 – $PM_{2.5}$ Concentration Old Bexley Church of England Primary School – Airly Data during school hours only



It can be seen from the $PM_{2.5}$ concentration data in Old Bexley Church of England Primary School (**Figure 4-5**) that median $PM_{2.5}$ concentrations within the larger commercial AFS classroom appears to be consistently lower than the control classroom median $PM_{2.5}$ concentrations. In addition, as illustrated in **Figure 4-4**, the control classroom appeared to have experienced higher $PM_{2.5}$ concentrations within the diurnal variation plots and weekday average plots. $PM_{2.5}$ concentration differences between the larger commercial AFS classroom and the control classroom were also notable, at up to 4.5 $\mu g/m^3$ as a daily average.

OLD BEXLEY CHURCH OF ENGLAND PRIMARY SCHOOL MONITORING DATA SUMMARY

$PM_{2.5}$ average and concentration differences between control classrooms and filtered classrooms for school hours only are outlined in **Table 4-2** below.

Table 4-2 – $PM_{2.5}$ Concentration Differences between Control and Filtered Classrooms Old Bexley Church of England Primary School during school hours only

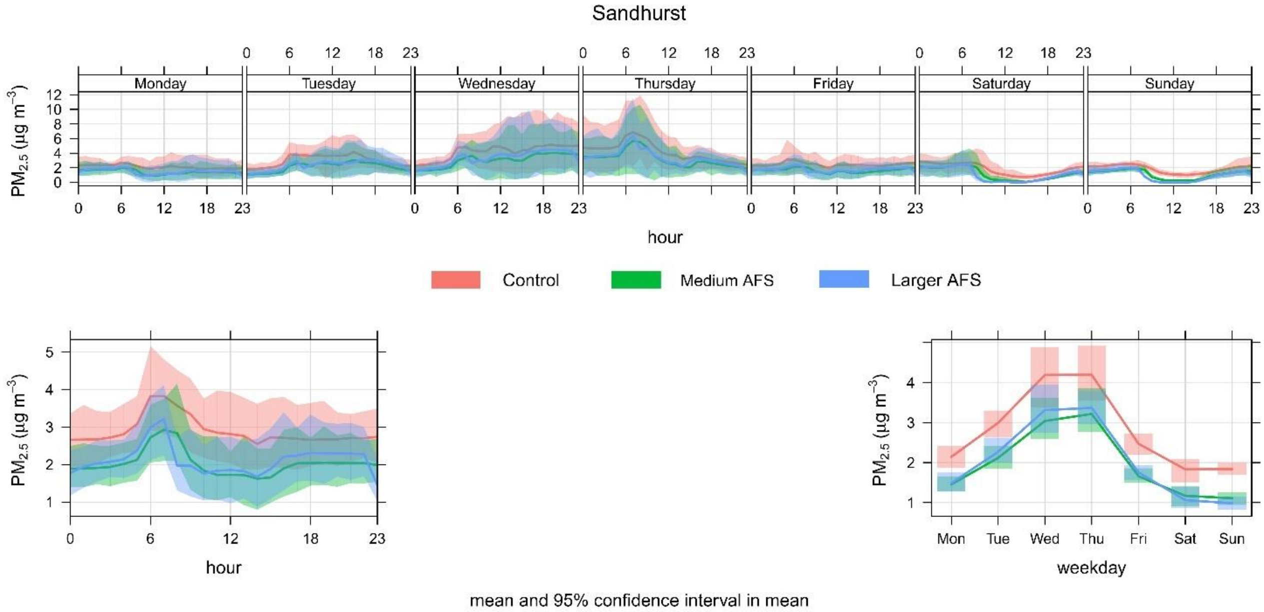
Air Filtration	Airly	
	$PM_{2.5}$ Average ($\mu g/m^3$)	Concentration Differences between Control
Control	3.23	-
Medium commercial AFS	1.92	-50.80%
Larger commercial AFS	1.59	-68.39%

4.4 SANDHURST PRIMARY SCHOOL MONITORING DATA

AIRLY MONITORING DATA

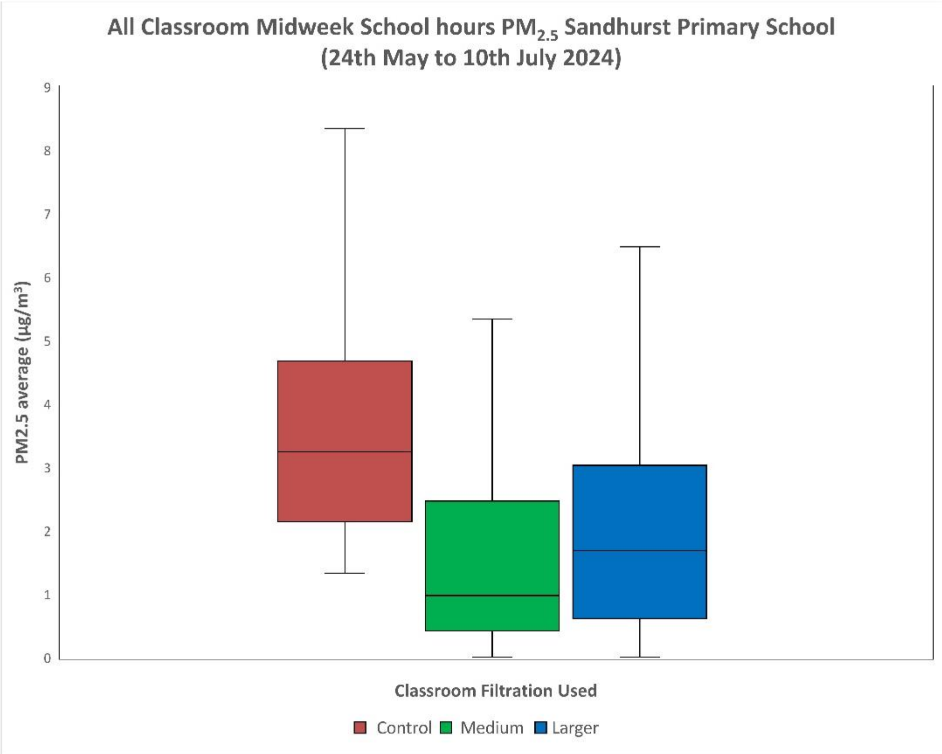
Airly concentration data has been gathered for all classrooms monitored at Sandhurst Primary School. A series of plots have been undertaken using the open source analytical tool 'OpenAir'. These include time series, diurnal variation, monthly averages and daily averages for all classrooms monitored (**Figure 4-6**).

Figure 4-6 – Summary Airly $PM_{2.5}$ concentrations across the filtered and Control Classrooms Sandhurst Primary School 28/05 - 28/06/2024



A DIY AFS was placed within a classroom which was infrequently occupied and positioned on the first floor of the school building, therefore not comparable to other tested classrooms. Therefore, $PM_{2.5}$ concentration data from this classroom was consistently lower than all other classrooms over the monthly average. As it is not comparable and for clarity, this DIY AFS has been removed from **Figure 4-6**, **Figure 4-7** and **Figure 4-8**. DIY filter data can be viewed in **Appendix B** alongside averaged data for all other filters and monitors.

Figure 4-7 – $PM_{2.5}$ Concentration Sandhurst Primary School – Airly Data

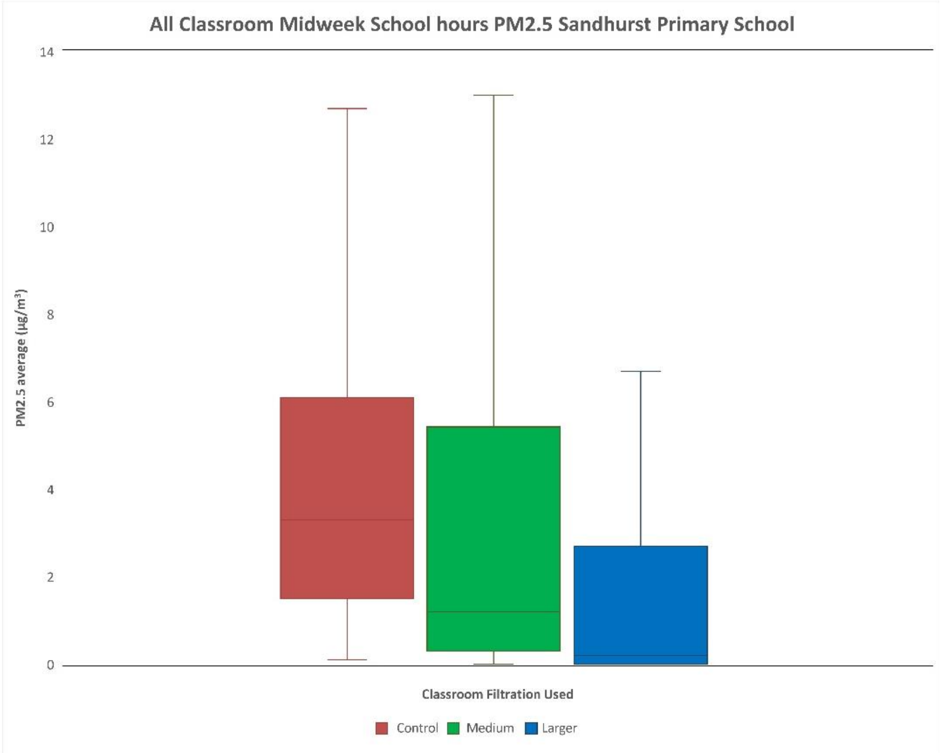


$PM_{2.5}$ concentrations within classrooms with both medium commercial AFS and larger commercial AFS during school hours at Sandhurst Primary School (**Figure 4-7)**, were observed to be similar, and consistently lower that of the control classroom. The control classroom appears to be experiencing higher $PM_{2.5}$ concentrations within the diurnal variation plots and weekday average plots (**Figure 4-6**), with both the medium commercial AFS and the larger commercial AFS classrooms indicating markedly lower $PM_{2.5}$ concentrations. In the Boxplots (**Figure 4-7**) differences in median $PM_{2.5}$ concentrations between the larger commercial AFS classroom and the control classroom can be seen as up to 2.0 $\mu g/m^3$, during school hours over the reported period.

AIR GRADIENT MONITORING DATA

$PM_{2.5}$ concentration monitoring data from the Air Gradient at Sandhurst Primary School can be seen in **Figure 4-8** below. Once again concentrations were observed to be lower within the larger commercial AFS classroom in relation to the control classrooms, and lower than all other monitored classrooms. Median $PM_{2.5}$ concentration differences between the larger commercial AFS classroom and the control classroom can be seen as up to 0.8 $\mu g/m^3$.

Figure 4-8 - $PM_{2.5}$ Concentration Sandhurst Primary School – Air Gradient Monitoring



SANDHURST PRIMARY SCHOOL MONITORING DATA SUMMARY

$PM_{2.5}$ average and concentration differences between control classrooms and filtered classrooms for school hours only are outlined in **Table 4-3** below.

Table 4-3 – $PM_{2.5}$ Concentration Differences between Control and Filtered Classrooms Sandhurst Primary School during school hours only

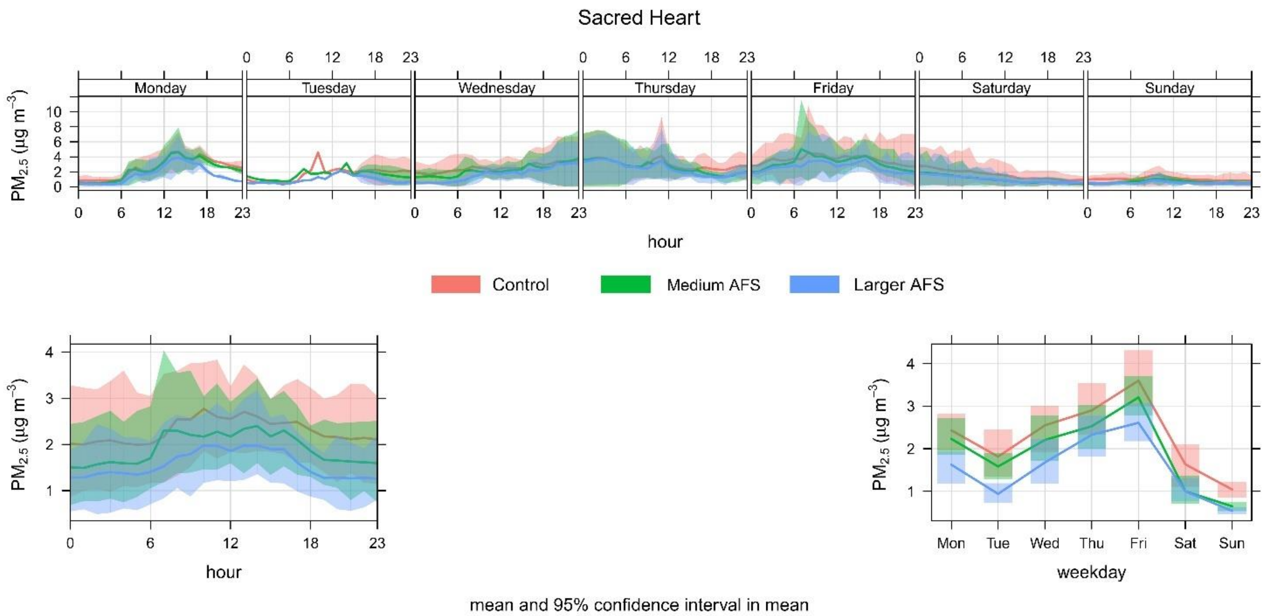
Air Filtration	Airly		Air Gradient	
	$PM_{2.5}$ Average ($\mu g/m^3$)	Concentration Differences between Control	$PM_{2.5}$ Average ($\mu g/m^3$)	Concentration Differences between Control
Control	2.98	-	4.38	-
Medium commercial AFS	1.96	-41.45%	3.04	-35.87%
Larger commercial AFS	2.07	-35.83%	1.90	-78.97%

4.5 SACRED HEART CATHOLIC PRIMARY SCHOOL MONITORING DATA

AIRLY MONITORING DATA

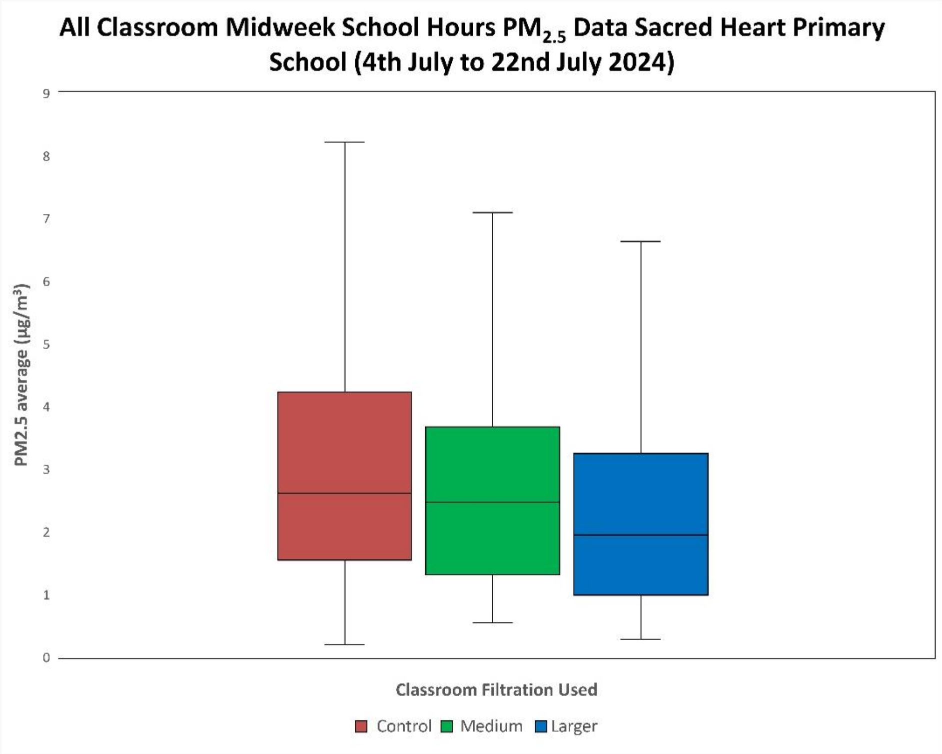
Airly concentration data has been gathered for all classrooms monitored at Sacred Heart Primary School. A series of plots have been undertaken using the open source analytical tool 'OpenAir'. These include time series, diurnal variation, monthly averages and daily averages for all classrooms monitored (**Figure 4-9**).

Figure 4-9 – Summary Airly $PM_{2.5}$ concentrations across the filtered and Control Classrooms Sacred Heart Primary School 04/07 - 22/07/2024



Within **Figure 4-9**, above, the control classroom appears to be experiencing higher $PM_{2.5}$ concentrations within the diurnal variation plots and weekday average plots, with the medium commercial AFS classroom indicating lower $PM_{2.5}$ concentrations.

Figure 4-10 – $PM_{2.5}$ Concentration Sacred Heart Primary School – Airly Data



It can be seen from the $PM_{2.5}$ concentration data from Sacred Heart Primary above (**Figure 4-10**), that median $PM_{2.5}$ concentrations within the larger commercial AFS classroom appears to be consistently lower than all other classrooms. Median $PM_{2.5}$ concentration differences between the larger commercial AFS classroom and the control classroom can be seen as up to 0.8 $\mu g/m^3$.

SACRED HEART PRIMARY SCHOOL MONITORING DATA SUMMARY

$PM_{2.5}$ average and concentration differences between the control classroom and filtered classrooms for school hours only are outlined in **Table 4-4** below.

Table 4-4 – $PM_{2.5}$ Concentration Differences between Control and Filtered Classrooms Sacred Heart Primary School during school hours only

Air Filtration	Airly ($\mu g/m^3$)	
	$PM_{2.5}$ Average ($\mu g/m^3$)	Concentration Differences between Control
Control	3.20	-
Medium commercial AFS	2.95	-7.85%

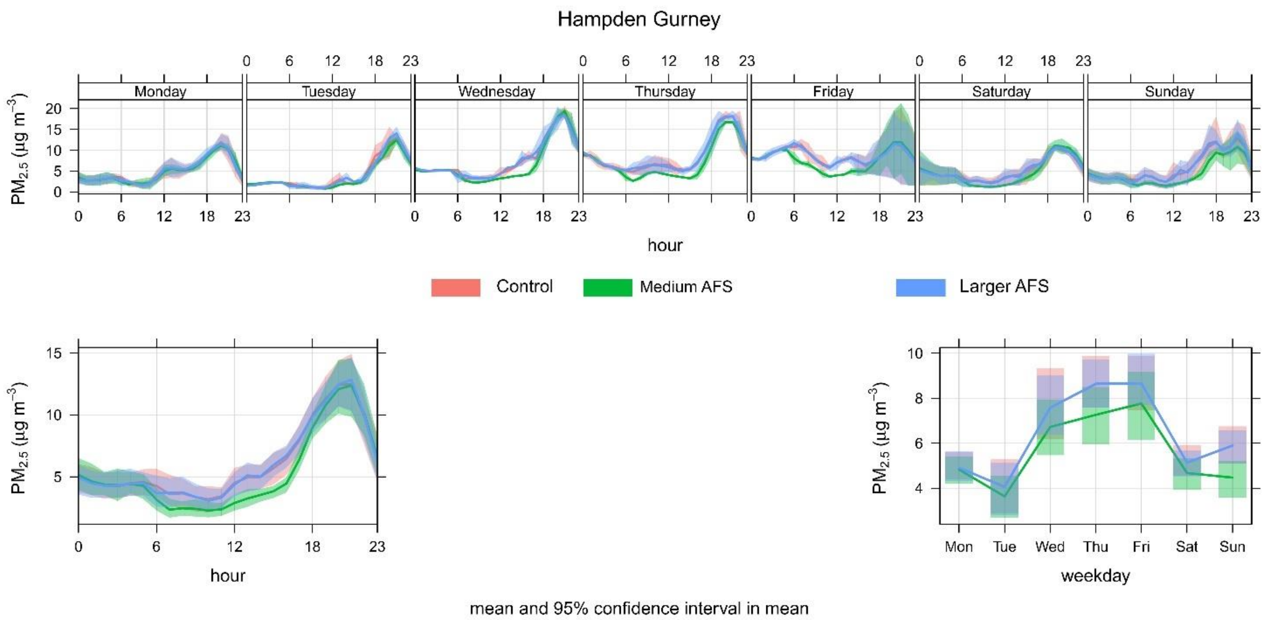
Larger commercial AFS	2.44	-28.00%

4.6 HAMPDEN GURNEY PRIMARY SCHOOL MONITORING DATA

AIRLY MONITORING DATA

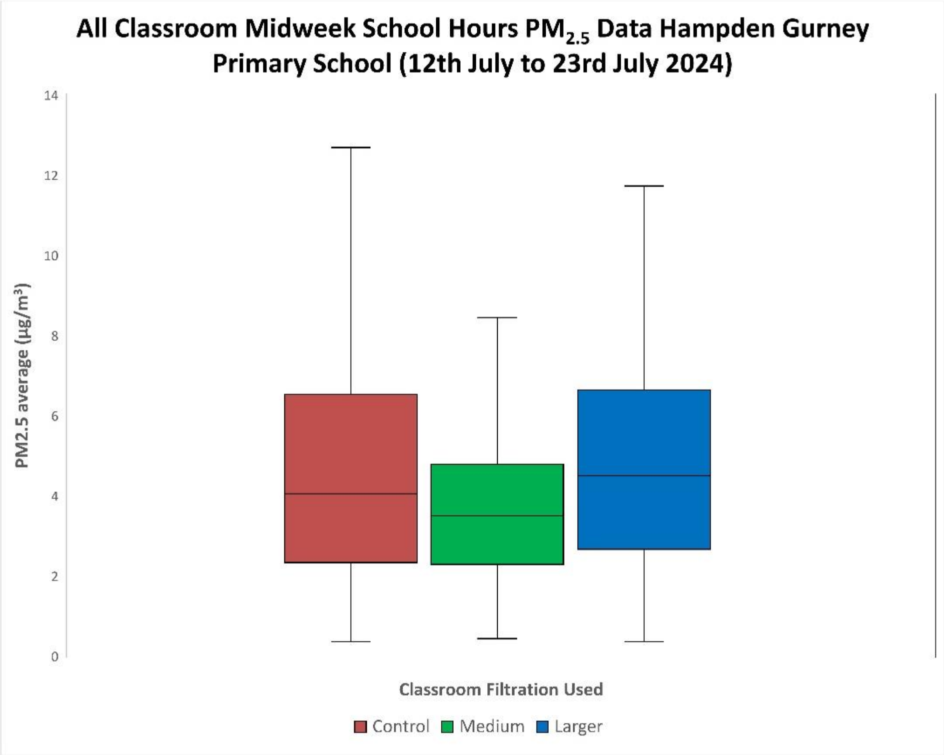
Airly concentration data has been gathered for all classrooms monitored at Hampden Gurney Primary School. A series of plots have been undertaken using the open source analytical tool 'OpenAir'. These include time series, diurnal variation, monthly averages and daily averages for all classrooms monitored (**Figure 4-11**).

Figure 4-11 – Summary Airly $PM_{2.5}$ concentrations across the filtered and Control Classrooms Hampden Gurney Primary School 12/07 - 22/07/2024, during school hours only



The medium commercial AFS classroom appears to be experiencing lower $PM_{2.5}$ concentrations within the diurnal variation plots and weekday average plots, with both the control classroom and the larger commercial AFS classroom indicating higher $PM_{2.5}$ concentrations.

Figure 4-12 – $PM_{2.5}$ Concentration Hampden Gurney Primary School – Airly Data

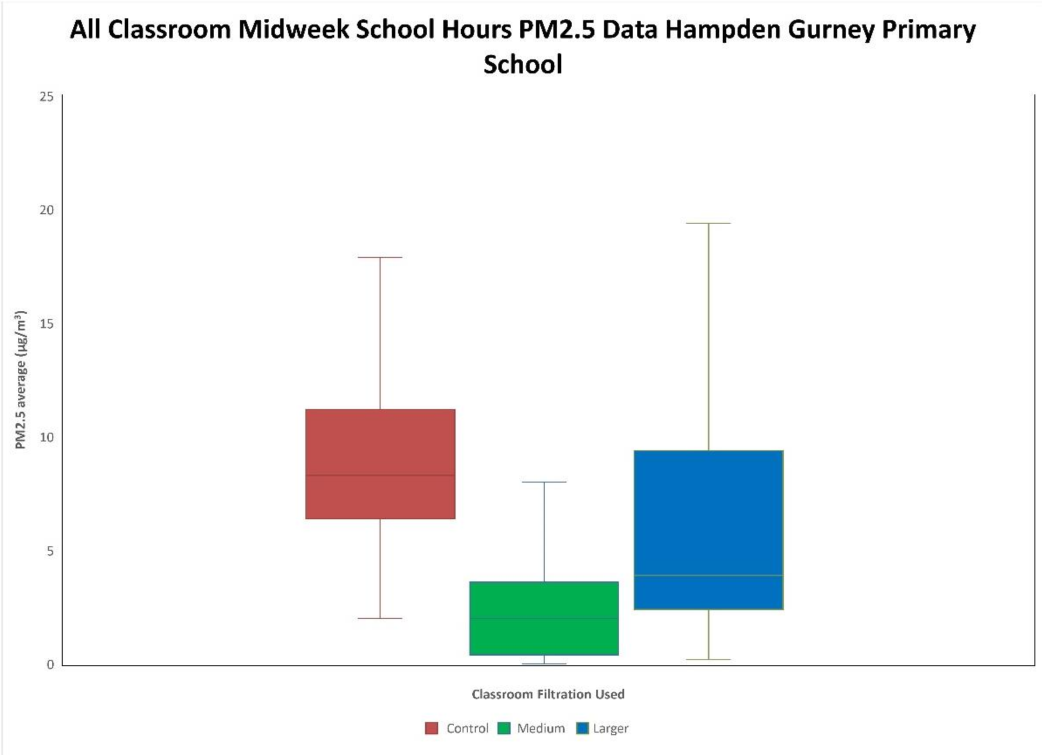


It can be seen from the $PM_{2.5}$ concentration data from Hampden Gurney Primary School above (**Figure 4-12**), that concentrations differences appear to be less defined across the monitored classrooms. Data from the larger commercial AFS classroom indicated a higher median $PM_{2.5}$ concentration than other air filtration classrooms, as well as the control classroom. The medium commercial AFS classroom appears to be consistently lower than all other classrooms over the averaged period. $PM_{2.5}$ concentration differences between the medium commercial AFS and the control classroom can be seen as up to 0.8 $\mu g/m^3$.

AIR GRADIENT MONITORING DATA

$PM_{2.5}$ concentration monitoring data from the Air Gradient at Hampden Gurney Primary School can be seen in **Figure 4-13** below. $PM_{2.5}$ concentrations within the medium commercial AFS classroom appear to be consistently lower than all other classrooms. Median $PM_{2.5}$ concentration differences between the medium commercial AFS classroom and the control classroom can be seen as up to -5.0 $\mu g/m^3$, and up to -3.0 $\mu g/m^3$ for the larger commercial AFS.

Figure 4-13 - $PM_{2.5}$ Concentration Hampden Gurney Primary School – Air Gradient Monitoring



HAMPDEN GURNEY PRIMARY SCHOOL MONITORING DATA SUMMARY

$PM_{2.5}$ average and percentage differences between control classrooms and filtered classrooms for school hours only are outlined in **Table 4-5** below.

Table 4-5 – $PM_{2.5}$ Concentration Differences between Control and Filtered Classrooms Hampden Gurney Primary School

Air Filtration	Airly		Air Gradient	
	$PM_{2.5}$ Average (µg/m³)	Concentration Differences between Control	$PM_{2.5}$ Average (µg/m³)	Concentration Differences between Control
Control	4.52	-	8.64	-
Medium commercial AFS	3.69	-20.20%	2.19	-119.26%

Larger commercial AFS	4.84	6.82%	5.66	-41.72%

4.7 PERFORMANCE DIFFERENCES

For the five schools involved in this research, $PM_{2.5}$ concentrations appeared to be notably lower in comparison to the control (non-filtered) classrooms, with an exception.

Operationally the larger commercial AFS appeared to have been most effective at improving air quality within the classroom in comparison to the adjacent control classroom. However, there was an exception at Hampden Gurney Primary School, located in central London, where the detected $PM_{2.5}$ concentrations were observed to be highest in the classroom with the larger commercial AFS installed. This was contradictory to the results from the four other schools, and could be related to either behaviour such as opening classroom windows allowing polluted air into the classroom, or interference in the operation of the larger commercial AFS device (e.g. staff switching it off periodically), thereby reducing its effectiveness in that particular instance.

4.8 INSTALLATION CONSTRAINTS

Installation of the AFSs were subject to multiple and varying constraints within the school environment, as well as the physical and logistical challenges of introducing new equipment into a confined and dynamic classroom environment.

WILLINGNESS OF CANDIDATE SCHOOLS

The initial constraint of the installation process was found to be the recruitment and willingness of schools to participate within the study.

ACCESS TO ELECTRICAL SOCKETS

As all AFSs and monitors required mains power, access to available electrical sockets within the classroom was a requirement for installation of the AFS and monitors. All schools had a policy of no electrical extension leads, so equipment had to be located close to any available power socket. One interested candidate school had to be turned down on the basis that all classrooms had only been supplied with two electrical sockets, which had already been allocated to essential classroom equipment.

SAFETY OF EQUIPMENT INSTALLATION

Due to the dynamic nature of primary school classrooms, it was critical that AFSs were positioned in classroom location which was both safe and unobstructive. This was often difficult to ensure, and on several occasions, classrooms were not chosen due to their confined nature, and lack of suitability. This was particularly relevant in several key stage one (earlier years) classrooms, where concerns of falling equipment striking younger children was raised, or collision risk was considered very high.

POSITION OF AIR FILTRATION SYSTEMS AND MONITORING DEVICES

The positioning of both AFSs and monitoring devices were to be separated by several metres (minimum 3m) in order that the monitoring devices were able to collect a representative sample of classroom air. Ensuring that the two devices had sufficient separation and were positioned away from classroom window or doors (to avoid filtering or sampling outside air) was a challenge. It was not always possible to position air quality monitors in an optimal location due to the constrained nature of the classrooms sampled. Several classrooms were not selected due to insufficient separation of monitors and AFSs.

5 DISCUSSION AND CONCLUSIONS

5.1 DISCUSSION

Installations of both AFSs and air quality monitoring devices into classrooms have been completed at five London primary schools as part of this research project.

KEY OUTCOMES

Monitoring $PM_{2.5}$ in classrooms using Airly monitoring devices where AFSs were deployed across 5 schools resulted in 10 classrooms out of 11 experiencing a reduction in $PM_{2.5}$ concentrations, when compared to the classroom where no AFS was deployed. The most notable reduction occurred at Old Bexley Church of England School, and the least effective filtration was at Hampden Gurney Primary School.

Monitoring using Air Gradient devices at all 3 of the schools where Air Gradient monitors were deployed indicated that $PM_{2.5}$ concentrations appeared to be lower in the classrooms that were installed with filters than was the case in control classrooms, with the exception being the DIY AFS.

$PM_{2.5}$ concentrations detected within control classrooms across the monitoring period during school hours were low. Most of the schools monitored were in areas of relatively low pollution. Monitoring was also undertaken outside of winter months when indoor air quality can be poorer, for example, due to heating.

Monitored levels were less than half the annual average recommended WHO guideline value[6] for $PM_{2.5}$ of 5 $\mu g/m^3$. Filtering classroom air in most instances reduced these concentrations further, likely to well below the annual average WHO guideline of 5 μg/m. However, as noted, in winter months concentrations are likely to be higher, and in more polluted areas the classroom concentrations are likely to be significantly increased. It is therefore important that any roll out focuses on schools in the most polluted areas.

[6] WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide, 2021

Furthermore, there is no safe level of air pollution and any improvement to levels of $PM_{2.5}$ has the potential to help protect the health of school children.

Performance of AFSs within classroom settings were subject to additional factors such as location of classrooms, position of AFSs, opening windows or classroom door for ventilation, and interference of the filtration and / or monitors by school staff.

The percentage differences in $PM_{2.5}$ concentrations using Airlys monitoring devices (with limited Air Gradient data in brackets) between the control classroom and the classrooms with AFSs are summarised for all 5 school in **Table 5-1** below.

Table 5-1 –Airly Monitoring Data $PM_{2.5}$ Concentration Differences between Air Filtration Systems and Control in all School Classrooms (Air Gradient data in brackets)

	% Difference $PM_{2.5}$ concentration between to control		
School	**Medium commercial AFS**	**DIY AFS**	**Larger commercial AFS**
Less Ness Heath Primary School	-26.28	-0.04 (7.94)	-38.16 (-27.59)
Old Bexley Church of England Primary School	-50.80	-	-68.39
Sandhurst Primary School	-41.45 (-35.87)	-	-35.83 (-78.97)
Sacred Heart Primary School	-7.85	-	-28.00
Hampden Gurney Primary School	-20.20 (-119.26)	-	6.82 (-41.72)

Across the 5 schools where AFSs were deployed, combined Airly and Air Gradient monitoring data implies that there was only a single occasion where the AFS did not reduce classroom $PM_{2.5}$ concentrations in relation to the adjacent control classroom. This occurred with one of the larger commercial AFSs deployed at Hampden Gurney. It can be observed that the medium commercial AFS deployed at Hampden Gurney, also seemed to not have reduced $PM_{2.5}$ concentrations as much as at other schools.

It is probable that the failure to detect reductions in $PM_{2.5}$ concentrations at Hampden Gurney Primary school with Airly data for the larger commercial AFS could be due to the AFSs being switched off periodically, impacting the effectiveness. However, although the Airly monitoring data didn't show an improvement, the Air Gradient data for Hampden Gurney Primary School indicated that there was a reduction in $PM_{2.5}$ concentrations in both classrooms. Data from two monitors may differ because of where monitors were located, as monitors could be influenced by natural ventilation, such as open windows or doors, or relocated closer to air filtration devices. In addition, both the Airly and Air Gradient process air quality data using slightly differing processes, and generally are not considered to be equivalent.

Overall performance of the manufactured AFSs appears to be positive, in terms of their ability to reduce $PM_{2.5}$ concentrations in most instances, as well as being suitable for a classroom setting.

5.2 CONCLUSIONS AND RECOMMENDATIONS

WSP's trial of deploying a range of AFSs across 5 primary schools in London has indicated that AFSs are generally considered to be practical and can be effective at reducing $PM_{2.5}$ concentrations within classrooms.

SUCCESSES AND FAILURES

This research project has indicated that installation of AFSs in classrooms of London schools can reduce pupil exposure to $PM_{2.5}$ within the classroom by, between 0.8 to 2.0 $\mu g/m^3$ over the school day. In some instances, classrooms with the larger commercial AFS and medium commercial AFS had a difference in concentrations classroom of between 68% and 51% respectively compared to the relevant control classroom.

The study has proven that deploying AFSs in primary school classrooms can reduce average $PM_{2.5}$ concentrations, even when $PM_{2.5}$ is already below WHO recommended guideline values. At Hampden Gurney Primary School the medium commercial AFS was found to be the most effective at that particular location. At all of the remaining schools, the larger commercial AFS was found to be the most effective at reducing $PM_{2.5}$ concentrations.

Upon decommissioning of the AFSs, comments and feedback from classroom staff and school staff were collated by WSP. There were no negative comments or observations, and classroom staff complemented the presence of AFSs, and generally welcomed their presence and use, with no negative comments of the three commercial AFSs regarding obstruction, noise or vibration from school staff, management or school leaders.

The only device removed was the DIY device from Old Bexley Church of England Primary School due to safety concerns. After initial discussions with school staff during installation, the DIY device was not deployed in either Sacred Heart Primary School, or in Hampden Gurney Primary School.

Information gathered during installation and follow-up communications with the schools suggested that the DIY AFSs were unpopular. This was partly due safety concerns, size and some reports of excessive noise. During installation, WSP site staff made it clear to school staff that the DIY AFS could be switched off or removed should there be any safety concerns or interference with classroom activities/ambience.

POTENTIAL ADAPTATIONS

Within Less Ness Heath Primary School, a number of classrooms had pre-existing AFSs, which had been in place for a number of months. The school chose to deploy two medium commercial AFSs within classrooms rather than single larger systems, allowing a similar volume of air to be filtered through with better distribution across the classroom, with less low noise interference and less obstructive.

Should the deployment of AFSs continue and expand within London schools, WSP advise the GLA should take into account:

- Commercial AFSs were largely well received by classroom and school staff with no complaints of noise, obstruction or disruption to the classroom activities.
- Practicality and effectiveness of DIY AFSs may be limited. In this small-scale study, they appear to be less consistent and less well received than the manufactured AFSs tested.

- The clean air delivery rate of the selected AFSs should be appropriate for the classroom size to be filtered, otherwise too low an air cleansing rate will result in poor performance, and too high an air cleansing rate could result in classroom cooling and unwarranted noise nuisance.
- Locations for positioning the AFS should take regard of any open windows or doors, as positioning too close to these will dilute the effectiveness of the AFS.
- Where AFSs are to be deployed, allowing classroom staff to be able to control the air flow rate will greatly assist in the AFSs function and use. As classroom staff may switch the AFS off, if it is too noisy or its air flow rate is overcooling the classroom.

Appendix A

MONITORING DEVICE TECHNICAL DATA SHEETS

Airly Air Quality Sensors

Product Card

General information

Available protocols for communication

- GSM

Particulate matter concentration measurement

	Range	Accuracy
PM1.0	0 – 500 µg/m³	± 1 µg/m3
PM2.5	0 – 1000 µg/m³	± 1 µg/m3
PM10	0 – 1000 µg/m³	± 1 µg/m3

Measurements interval

- Airly PM Sensor: 5 min
- Airly PM+GAS Sensor: 5 min

Power supply

- Powered by: 5V@2A from external USB
- Power supply: (230V/110V)
- Power supply cable length: 2.9 m
- Solar power supply: available
- Average power consumption: 1.2 W
- Max. power consumption: 2 W
- Energy consumption (per 24h): 0.03 kWh
- Energy consumption (per year): 10.5 kWh

Data accessibility

- Airly website map.airly.org
- Airly Mobile app iOS, Android and Huawei
- Widget
- Airly API
- Airly Data Platform (ADP)

Installation requirements

- GSM range: min -90 dBm
- Access to power: The sensor must be permanently connected powered if you can't meet this recommendations for your destination, consider using the sensor with the power system solar energy.
- Height: 1.5 – 8 m above the ground

airly

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Technical specification

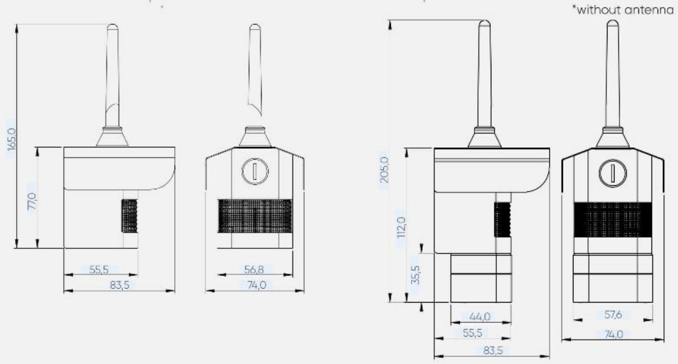
	Airly PM Sensor		Airly PM+GAS Sensor	
Constant working conditions				
Temperature	-40°C – +80°C		-40°C – +80°C	
Humidity	0 – 100%		0 – 100%	
Pressure	700 – 1 200 hPa		700 – 1 200 hPa	
Measurements				
	PM1, PM2.5, PM10, temperature (°C), pressure (hPa), humidity (%)		PM1, PM2.5, PM10, temperature (°C), pressure (hPa), humidity (%	
			types: NO_2+O_3, SO_2+CO, NO_2+NO	
	Range	Accuracy	Range	Accuracy
Temperature	-40°C – +80°C	± 0,1°C	-40°C – +80°C	± 0,1°C
Pressure	700 – 1 200 hPa	± 1 Pa	700 – 1 200 hPa	± 1 Pa
Humidity	0 – 100%	± 1%	0 – 100%	± 1%
Measurement frequency				
Sampling Interval	1-2 sec		1-2 sec	
Averaging Interval	5 min		5 min	
Interwał wysyłania	5 min		15 min (3 samples with a 5-minute average)	

Both sensors (in Low Power mode)	Sampling Interval	sending interval	Sleep time
	1-2 sec every 4 min	20 min	16 min

Gas concentration measurement	Range	Accuracy
NO	0 – 5 000 ppb	± 1 ppb
NO_2	0 – 5 000 ppb	± 1 ppb
O_3	0 – 5 000 ppb	± 1 ppb
SO_2	0 – 5 000 ppb	± 1 ppb
CO	0 – 20 000 ppb	± 1 ppb

Enclosure parameters and weight	Airly PM Sensor	Airly PM+GAS Sensor
Case material	Stainless steel	Stainless steel
Dimensions	74 x 77* x 83,5 mm	74 x 112* x 83,5 mm
Device weight	440g	490g

*without antenna



2024 05 v 01

open source hardware

airgradient

Indoor Air Quality Monitor

AirGradient ONE (Model: I-9PSL)

AirGradient ONE is an indoor air quality monitor enabling you to know if the air quality is healthy or not. It measures CO2, PM2.5, TVOCs, NOx, Temperature and Humidity.
It's easy to assemble, fully open-source and customizable, so you can extend it in whatever way you like.

The AirGradient ONE is also available as an easy to assemble kit.

Technical Data

Specification	Description
Model	I-9PSL (AirGradient ONE, 9th Generation)
Microcontroller	ESP32-C3-MINI (32-bit RISC-V single-core processor, up to 160MHz, 384 KB ROM, 400 KB SRAM, 8 KB SRAM in RTC, 4 MB flash in chip package)
WiFi	2.4GHz IEEE 802.11 b/g/n-compliant
Bluetooth	Bluetooth LE: Bluetooth 5, Bluetooth mesh
Extensions	Broken out on PCB: I2C, 3 GPIO, 2 UART
Peripherals	11 RGB-LEDs, Push Button, Reset Button, USB C Connector
External Hardware Watchdog	Texas Instruments TPL5010
CO2 Sensor Module	SenseAir S8 (NDIR). 400 to 10000ppm. Accuracy: ±40 ppm ±3% of reading at 5 to 30°C, 20-70%RH (400 - 2000ppm range)
Particle Sensor Module	Plantower PMS5003 (laser scattering principle). Accuracy: ±10%@100~500μ g/m³, ±10μg/m³@0~100μ g/m³
Temperature and Humidity	Sensirion SHT40. Accuracy: Temperature ±0.2°C @ -40 to + 125°C; Humidity ±2% RH @ 0 - 100% RH
TVOC/NOx Module	Sensirion SGP41. Accuracy: TVOC <±15 @ 0 to 500 VOC Index; NOx <±50 @ 0 - 500 NOx Index
Enclosure	ASA Plastic, UV Resistant and Weather Proof
Mounting Options	Wall or pole mounting options
Cable	2m USB C Cable including data lines for flashing
Certifications	CE, RoHS, REACH, FCC ID: 2AC7Z-ESPC3MINI
License	Open Source Hardware licensed under CC-BY-SA

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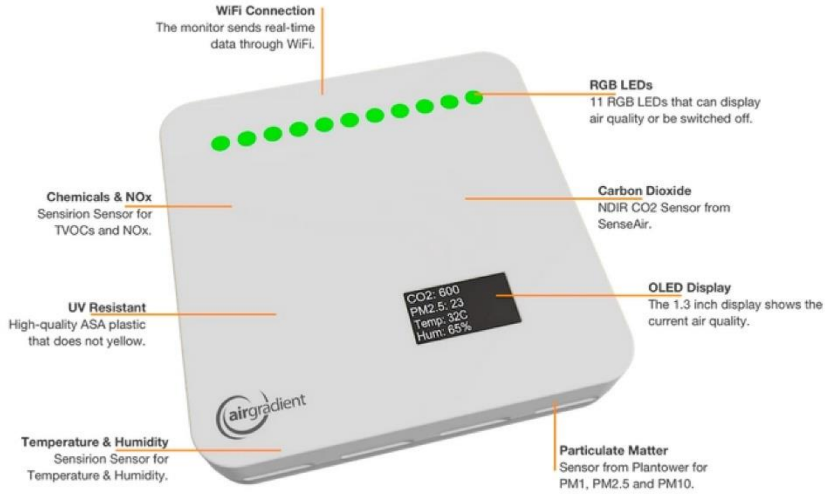
Key Characteristics

AirGradient uses high quality sensor modules from industry leaders SenseAir, Sensirion and Plantower.



What does it measure?

The SenseAir S8 CO_2 sensor utilizes NDIR technology for very accurate measurements. It auto calibrates with an automatic baseline calibration (ABC) every 7 days. High levels of CO_2 can indicate insufficient ventilation and cause headaches, tiredness and lower cognitive performance.

For PM2.5 measurements, the AirGradient uses the Plantower PMS5003 sensor with laser scattering technology that has been extensively tested in various studies. Elevated levels of fine particles -especially below 2.5 microns - has been linked to a broad range of health issues including premature mortality, heart or lung problems, acute and chronic bronchitis, asthma attacks, and respiratory symptoms. The sensor module is factory calibrated.

TVOC and NOx is measured with the Sensirion SGP41 TVOC/NOx sensor. TVOCs are organic chemicals that can easily vaporize and enter the air we breathe. These often do have indoor causes like off gasing furniture or aggressive cleaning liquids. NOx are harmful gases that can be caused by indoor gas stoves or boilers.

Temperature and Humidity are measured with the Sensirion SHT3x/4x sensors which are one of the most accurate ones in the market. These two air quality parameters can give you good information about indoor comfort levels and also indicate e.g. the risk of mold due to high humidity levels.

AirGradient started as a volunteer project in a school in Northern Thailand monitoring dangerously high air pollution levels in classrooms during the “burning season”.

Our mission is to enable people to breathe healthy air by providing open-source, reliable and accurate air quality monitors and supporting organizations and citizens in understanding the air quality in their communities.

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Appendix B

AVERAGED MONITORING DATA

Table B-1 – Average $PM_{2.5}$ Classroom Concentrations data during school hours for Air Filtration Systems, including DIY AFS

Air Filtration	Airly		Air Gradient	
	$PM_{2.5}$ Average (µg/m^3)	% Difference between Control	$PM_{2.5}$ Average (µg/m^3)	% Difference between Control
Control	3.70	-	6.95	-
Medium commercial AFS	2.81	-24.79%	2.62	-52.56
DIY AFS*	2.98	-53.14%	-	-
Larger commercial AFS	2.81	-25.99	4.49	-38.46

* A DIY AFS was placed in an unused Classroom with very low classroom activity on the first floor. Therefore, the data is not comparable to other tested classrooms in the body of the report but is presented here for completeness

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