Greater London Authority

THE MAYOR OF LONDON'S NURSERY AIR QUALITY AUDIT PROGRAMME

Air Filtration System Trial

AFS
FEBRUARY 2020

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EXECUTIVE SUMMARY

Improving air quality is a priority for the Mayor of London given its significant health impacts, especially on the young and vulnerable. The Mayor wants London to have the best air quality of any major world city by 2050, achieving both legal Nitrogen Dioxide pollution limits by 2025 and World Health Organization recommended guidelines for Particulate Matter (PM) by 2030. He is taking action to address pollution emissions at source, including by cleaning up the bus and taxi fleets and by introducing the Ultra Low Emission Zone. In addition to these, the Mayor has wanted to take steps to reduce exposure, particularly at schools and nurseries.

This **report presents the findings of a 6-month trial of Air Filtration Systems (AFS)** in six nursery schools, as part of a wider programme of air quality audits undertaken on behalf of the Greater London Authority (GLA) at nursery schools in areas of high pollution, to enable nurseries to make an informed choice about whether to install AFS

The objectives of the trial were to:

- Assess the context and feasibility of installing filtration systems at the selected nurseries.
- Install, trial and monitor the effectiveness of filtration systems in six nurseries, including consideration of installation and maintenance.
- Consider whether the technology was effective and appropriate for wider use in nurseries.

The trial **tested the effectiveness of the AFS at reducing indoor air pollution**, with a focus on reducing key air pollutants (NO_2), and particulate matter (PM_{10} and $PM_{2.5}$), as research shows that young children exposed to these pollutants are more likely to develop lung problems and breathing difficulties as they grow up.

Whilst AFSs are well established technologies, this trial was **seeking to test their suitability in dynamic "real world" nursery environments**, where windows and doors are open and children free-flow between classrooms and playgrounds throughout the day.

The intention of this trial has been to **determine the general effectiveness of the AFS** technologies in these unique settings, rather than directly compare the performance of the selected AFS units with one another, as it was recognised each was operating in particular conditions. Consequently, the supplier's details are anonymised when reporting on each specific site, with assessments focusing on establishing the effectiveness of each AFS in its given environment.

What is an Air Filtration System?

An AFS is a device that removes or reduces particles and pollutants within an environment. They **operate using a range of different technologies** (often in combinations) to remove particulate matters and harmful gases.

Mechanical filtration is the simplest and the most commonly used and established form of filtration, and has been used in engineering for decades. This approach entails trapping air particles in the filter without altering them. High-efficiency particulate arresting (HEPA) filters are often used.

Chemical methods - Carbon activated filters adsorb gases and odours as air passes through them. HEPA filters can be combined with carbon filters to eliminate odours and gases in the air, and capture Volatile Organic Compounds (VOCs, which are common constituents of household cleaning products and air fresheners). The only limitation is that the carbon filter increases the resistance to air flow, so requires a more powerful fan. Other chemical methods include the use of UV radiation to initiate a chemical reaction that may cleave VOC compounds.

Ionization / Electrostatic precipitation - works by using ionisation to charge dust particles which can then be collected on metal plates or in a mechanical filter. Ionization produces small amounts of ozone (O_3). itself another harmful gas, and so must be eliminated or reduced to nearly zero. Research has demonstrated that activated carbon is effective at removing ozone, so activated carbon filters often complement other filtration processes.

Although the principle of air filtration is well established, there are still **few widely recognised and robust technical standards** specific to stand-alone AFS. Whilst single components are widely regulated by standards and certifications, the AFS as a whole has no relevant standards and certifications to enable direct comparison of the models on the market.

Air Filtration Systems Selected for the Trial

A review was undertaken assessing commercially available AFS, with a focus on those with a removal capacity of PM and NO_x. A **shortlist of six AFS suppliers** were determined based on a range of criteria, with the suppliers invited to participate in the trial.

- Camfil
- IQair
- Radic8
- Blueair
- AeraMax Professional (Fellowes Brands)
- Airlabs

The shortlisted AFS units and the type of filter / technology within each unit are summarised below.

Summary of participating AFS suppliers

AFS		CAMFIL	IQAIR	BLUEAIR	RADIC8	AIRLABS	FELLOWES
Technology Type	PM Filter	X	X	X	X	X	X
	Carbon Filter	X	X	X	X	X	X
	UV				X		
	Titanium Dioxide Activated				X		
	Electrostatic/Ionisation			X		X	X

Nursery selection for the Trial

The **six participating nurseries were selected using an evidence based approach**, which included the findings of the air quality audit assessments, informed by site visits, baseline air quality monitoring in and around the nursery, and modelled air quality data.

- Columbia Market Nursery School (Tower Hamlets)
- Rachel McMillan Nursery School and Children's Centre (Greenwich)
- Nell Gwynn Nursery School (Southwark)
- Pembury House Nursery School (Haringey)
- Thomas Coram Centre (Camden)
- Dorothy Gardner Centre (Westminster)

A "**randomiser**" was used to assign each shortlisted AFS to one of the six nurseries. All the suppliers had the opportunity to undertake a site visit and propose the most suitable unit for the site.

Determining Indoor Air Quality During Air Filtration Systems Trial

A combination of **passive (diffusion tubes) and active (Zephyr) monitoring** techniques were used to determine internal air quality concentrations and trends during the AFS trial. **Ozone monitoring** was undertaken using two reference method ultraviolet photometry O_3 monitors.

The monitoring devices **sampled the classroom with the AFS and a separate "control classroom"** elsewhere within the nursery, with similar characteristics but no AFS installed. The effectiveness of the AFS system is represented by the difference between the AFS and control classrooms.

AFS Trial Results

The Zephyr data indicated that **all the AFS were successful in reducing $PM_{2.5}$** concentrations in classrooms during the monitoring periods. The classrooms with an AFS also appeared to have fewer peaks in $PM_{2.5}$ concentrations than those recorded in the corresponding control classroom.

Average **NO_2 concentrations from the diffusion tubes in the AFS classrooms were lower** than the control classrooms by between 1 to 4µg/m^3, though the diffusion tube results from Columbia Market, Nell Gwynn and Dorothy Gardner indicated that NO_2 concentrations were slightly higher in the AFS classroom than the control classroom.

Of the two testing methods deployed for NO_2, the **diffusion tubes provide a more accurate overall measure** of NO_2 concentrations over the course of a month, but in order to understand how and why NO_2 levels vary throughout each day, and to then be able to infer potential causes, a Zephyr continuous analyser is also used.

The **Zephyr data is less accurate in monitoring the overall levels of NO_2, but does provide useful data on the relative changes** in NO_2 on a minute-by-minute basis over the sampling period. As such, the two methods are often used in combination, and though the data may appear contradictory, it is more the case that these two different monitoring devices have different strengths and weaknesses.

Our assessments in terms of overall performance when it comes to NO_2 are more fundamentally informed by the diffusion tube data, but our interpretation as to why, including the potential sources of NO_2 and the performance of the AFS, is informed by the Zephyr data, to provide a more complete picture of what has taken place in the AFS and control rooms.

To ensure any ozone produced by the AFS was effectively mitigated, nurseries where AFS were installed which used electro static precipitation, ionisation or ultra-violet activation were also monitored for ozone. Where ozone was detected this was considered to be intrusion of external air and not the AFS present within the classrooms.

Summary of the AFS Monitoring Survey Pollutant Reduction Detected

Nursery	Effective NO_2 Reduction		Effective $PM_{2.5}$ Reduction	Effective Ozone Reduction
	Diffusion Tube	Zephyr		
Nell Gwynn	Negligible detected	Reduced peak hour NO_2 concentration in AFS classroom	Positive $PM_{2.5}$ reduction by approximately 0.8µg/m^3	Slight increase in O_3 detected
Columbia Market	Negligible detected	Reduced peak hour NO_2 concentration in AFS classroom	Positive $PM_{2.5}$ reduction by between 5 to 6µg/m^3.	Negligible difference detected
Rachel McMillan	N/A	Some minor reduction in AFS peak hour NO_2 in the afternoon, though minor increase in morning	Positive $PM_{2.5}$ reduction by approximately 0.3µg/m^3.	Negligible difference detected
Pembury House	Significant positive reduction with difference detected of 5.8µg/m^3	Significant NO_2 reduction in AFS throughout the day	Positive $PM_{2.5}$ reduction by up to 3µg/m^3	Positive O_3 reduction by between 4 to 6µg/m^3.
Thomas Coram	Successful positive reduction of 2.2µg/m^3 detected	Reduced peak hour NO_2 concentration in AFS classroom	Positive $PM_{2.5}$ reduction by between 0.2 to 1µg/m^3.	N/A
Dorothy Gardner	N/A	Reduction in NO_2 concentrations in AFS classroom	Positive $PM_{2.5}$ reduction by approximate 1 µg/m^3	N/A

Clear **differences were detected between the midweek and weekend sampling periods** in the classroom concentrations of NO_2 and $PM_{2.5}$, which is likely to be due to the intrusion of polluted air whilst windows and doors are open. Considering the need to reduce concentrations when the nursery is occupied in the weekday, the focus on the effectiveness of the AFS were during these midweek periods.

The **concentrations of NO_2, $PM_{2.5}$ and O_3 in all AFS and Control classrooms were all well below both ambient air quality limit values** (Table 3-1) and occupational health standards (Table 3-2).

Conclusion from Monitoring AFS

In conclusion this trial has established that **AFS can be effective at reducing $PM_{2.5}$, and to a lesser extent NO_2, in a real-world nursery environment**. The nursery classrooms that served as the testing ground for the trial exemplify **dynamic and unsealed environments**, with opened doors and windows, constantly varying occupancy and pupil movements, which has previously led many to express doubts about the ability of an AFS to operate effectively in such a setting. So for all of the AFS to be able to demonstrate a positive impact upon the nursery indoor air quality, reducing $PM_{2.5}$ and in some cases NO_2, is an encouraging outcome of this trial.

The trial also found that the **AFS units were suitable for installation and operation in a nursery environment**, with the experience of the nurseries found to be largely positive, with most remarking that the units were unobtrusive in terms of their presence in the classrooms, with low levels of noise and minimal requirements for space meaning they quickly faded into the background. In general, the wall-mounted units were felt to be better suited to a nursery environment.

As such, an **appropriately specified AFS could be duly considered amongst the range of measures[2] available for addressing poor air quality**, where the conditions are right (i.e. poor levels of indoor air quality, particularly PM, and where there is limited scope to directly influence the sources of emissions or otherwise reduce exposure), and ensuring the appropriate type of AFS is employed to match these conditions.

A benefit of AFS over some alternative measures is that they **can typically be deployed very quickly**, and should have an effect within hours. They are also relatively affordable, and whilst it would always be preferable to remove emissions at source, as opposed to retrospectively removing the pollutants from the air, measures to reduce emissions from passing traffic or surrounding buildings are often longer term projects, and beyond the influence of the nurseries to directly affect.

This trial noted that the six nurseries where the trial took place were within ambient air quality limit values, despite the nurseries being in amongst the most polluted areas of London, with their windows and doors open regularly, which serves to **underline the importance of establishing the baseline indoor air quality conditions** to inform the requirements for an AFS. Though it is important to note that other studies have found indoor air pollutants such as $PM_{2.5}$ were often significantly higher inside classrooms than outdoors, and that there are no entirely 'safe' levels of exposure to harmful pollutants, and children would still benefit from further reductions. The **low baseline concentrations of $PM_{2.5}$ will have constrained the ability of the AFS to reduce particulate concentrations**, and further demonstrate their particulate removal effectiveness.

It will be important for nurseries to **consider not only the upfront costs of the AFS units, but also the ongoing operating and maintenance costs**. We appreciate many of the nurseries are

[2] Toolkit of Measures to Improve Air Quality at Schools
https://www.london.gov.uk/sites/default/files/school_aq_audits_-_toolkit_of_measures_dr_v3.3.pdf

financially constrained, and the annual maintenance costs and energy consumption must be factored into any investment decisions. The operation of AFS will result in energy consumption and therefore potentially carbon emissions, subject to the generation source of the electricity.

We would recommend a life cycle and energy assessment be undertaken to ensure the nurseries can **fully account for the whole life costs** of the unit in their budgeting, including the costs of energy consumption and maintenance. These can be simple exercises undertaken by the nursery themselves, provided they know the filter price, operating hours and energy consumption of the unit.

Ultimately, whether a nursery should invest in an AFS is a very much an individual decision for each nursery and its staff. In our view, they **certainly have a role to play**, **targeting particular classrooms or high-use areas where indoor air quality is poor** (particularly in terms of PM where the AFS proved themselves to be most effective), where the need is pressing, and where there are few alternatives to stop the pollution at source. We would not advocate a blanket roll-out of AFS, mindful of the associated financial and environmental costs, and would **encourage an evidence based approach, to ensure AFS are deployed effectively.**

The **Healthy Streets approach** taken by Transport for London (TfL) and the Mayor of London promotes the creation of streets that are pleasant, safe and attractive, with a focus on reducing air pollution. This approach, alongside the application of the Toolkit of Measures developed as part of the Mayor's School Air Quality Audit Programme, remains key in reducing emissions at source.

Next Steps

It is also important that we recognise the limitations of this trial, and that whist the monitoring of the selected AFS 'in-situ' has provided a snapshot of their performance when deployed within nursery classrooms, to fully **quantify the impacts of AFS upon indoor air quality a series of controlled tests**, including testing using reference method monitoring instrumentation should be undertaken, and conducted across low, medium and high pollutant concentrations.

For consumers to be able to make informed decisions, **a common set of performance standards should be introduced**. We also advocate the development of AFS design standards, with minimum performance requirements, certified under common testing criteria by the Government or appropriate regulatory agencies.

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1

INTRODUCTION AND BACKGROUND

1 INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION

1.1.1. This report presents the findings of a 6-month trial of Air Filtration Systems (AFS) in six nursery schools, as part of a wider programme of air quality audits undertaken at nursery schools in areas of high pollution across London.

1.1.2. The report summarises the installation, trial and monitoring of a range of Air Filtration Systems, and the findings with regard their overall effectiveness in a real-world nursery environment. It also considers their wider impacts, such as noise, costs and observations and comments by the nursery staff. The trial methodology and any limitations are outlined in the reporting. The report concludes with consideration as to whether the technology was effective and appropriate for wider use in nurseries.

1.1.3. This report is structured as follows:

- Introduction & Background
- AFS research/ selection
- Nursery Selection and Baseline Air Quality Monitoring
- Trial Methodology
- AFS trial results
- Conclusions

1.2 BACKGROUND

1.2.1. Long-term exposure to poor air quality contributes to thousands of premature deaths in London. There is strong scientific evidence of the acute health effects of short-term exposure to very high pollution levels experienced during air pollution episodes.

1.2.2. Tackling air pollution is one of the Mayor of London’s top priorities. A recent study uncovered that 2 million Londoners are living in areas exceeding legal air limits, of which 400,000 are children. The Mayor recognises that co-ordinated action is required to reduce exposure, especially amongst the most

“It remains a shameful fact that London's toxic air health crisis is harming the lung growth and respiratory health of our young children, and City Hall is determined to everything in our power to protect them. These nursery audits focus on indoor pollution as well as outdoor sources, and will help us understand ways we can stop toxic air from our congested roads raising pollution limits inside nurseries.”

The Mayor of London, Sadiq Khan

vulnerable such as young children, whose lungs are still developing.[3]

1.2.3. The London Environment Strategy, published in May 2018, seeks to reduce the number of Londoners whose lives are blighted by poor air quality. The Mayor wants London to have the best air quality of any major world city by 2050, going beyond the legal requirements to protect human health and minimise inequalities. This include commitments to act to improve air quality in and around schools and nurseries and provide enhanced information to Londoners.

Why Nurseries?

1.2.4. The Mayor is particularly concerned about the impacts of poor air quality on vulnerable groups such as children, the elderly and those with pre-existing health conditions such as asthma and cardio-vascular diseases.

1.2.5. Young children are amongst the most vulnerable of the at-risk groups, as their lungs are still developing, and toxic air can stunt their growth, causing significant health problems in later life. The World Health Organization (WHO) also recognises younger children as being a vulnerable group to air pollution, making nurseries a key consideration in improving air quality.

1.2.6. A study led by Kings College in East London found that primary school children had on average 5% lower lung capacity than those growing up in rural areas. A UNICEF report published in December 2017 highlights the impact of air pollution on the critical growth that occurs in the brain in the first 1,000 days of life, making children exposed to pollution more vulnerable to developmental problems. UNICEF estimate that 17 million children globally are breathing air so toxic it is affecting their brain development.

1.2.7. Air pollution exacerbates asthma, which affects 1 in every 11 children in England.

Why Indoor Air Pollution?

1.2.8. Indoor Air Quality was recognised for the first time by the London Environment Strategy in 2018[4] as a serious issue that needs to be addressed. The report also highlights the relationship between indoor and outdoor air quality and why action needs to be taken.

1.2.9. A recent study[5] by University College London and the University of Cambridge, funded by the Mayor, found that indoor air pollution was significantly higher inside classrooms, due to a range of factors including the age of buildings, ventilation, positioning of windows, and wall-to-wall carpeting.

1.2.10. The study assessed five schools and one nursery as well as undertaking a literature review.

1.2.11. The findings suggested that the protection offered by the building increased the further away it was from the busiest roads, and that airtight buildings may offer greater protection against pollution.

[3] https://www.london.gov.uk/press-releases/mayoral/two-million-londoners-live-with-illegal-toxic-air
[4] https://www.london.gov.uk/sites/default/files/london_environment_strategy_0.pdf
[5] https://www.london.gov.uk/sites/default/files/gla_iaq_report_with_nts.pdf

1.2.12. The report also found that, in most classrooms, annual exposure to small particles was higher than recommended World Health Organization guidelines, and that this was caused by a combination of indoor and outdoor sources.

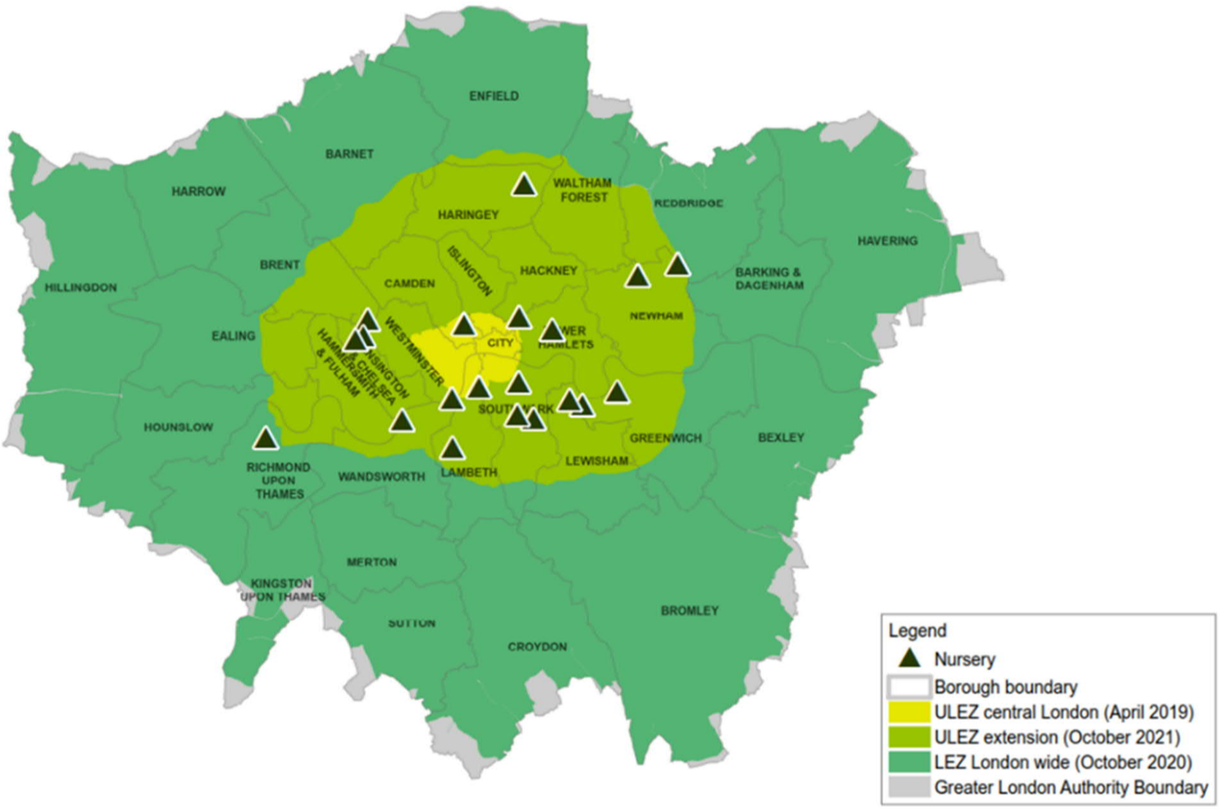
1.2.13. The impact of outdoor air pollution on indoor air quality underlines the importance of the hard-hitting measures the Mayors is already taking to tackle London's toxic air, including introducing the 24-hour Ultra Low Emission Zone in Central London and cleaning up the bus fleet.

The Mayor's Nurseries Air Quality Audits

1.2.14. In May 2018 the mayor launched a programme of air quality audits to help clean up toxic air and protect the health of young children in 20 nurseries in some of London's most polluted areas.

The Mayor's Nurseries Air Quality Audits Programme followed the approach developed as part of the Mayor's School Air Quality Audit Programme, identifying a combination of hard-hitting measures and quick win improvements, to minimise the impacts of toxic air on nursery children in some of the worse affected areas across London. This is both in terms of reducing the sources of harmful emissions, as well as reducing the exposure to these emissions.

Figure 1-1 - The Mayors Nursery Air Quality Audit Programme



1.2.15. The programme was led and funded by the Greater London Authority (GLA) and the audits were conducted by WSP, who have visited each of the nurseries, assessing indoor and outdoor air pollution sources, and how children travel to the nurseries.

1.2.16. The audits reviewed a range of methods to reduce pollution outside nurseries, including restricting road access outside entrances at drop off and collection times, moving playgrounds away from congested roads, installing green 'pollution barrier' hedges, tackling engine idling and promoting cycling and walking.

1.2.17. Built into the programme was a ring-fenced starter grant of £4,500 for each of the 20 nurseries to help kick-start recommendations on completion of the audits.

1.2.18. Following the audit assessments, 6 nurseries were selected from the 20 sites in the Air Quality Audit Programme as being suitable for trialling a range of AFS.

AFS Trial - Aims and Objectives

1.2.19. The AFS trials began in April 2019 and lasted for six months.

1.2.20. The objectives of the trial were to:

- Assess the context and feasibility of installing filtration systems at the selected nurseries
- Install, trial and monitor the effectiveness of filtration systems in six nurseries. This will include consideration of installation, maintenance and dismantling, the latter, if needs be.
- Consider whether the technology was effective and appropriate for wider use in nurseries.

1.2.21. The trial tested the effectiveness of the AFS at reducing indoor air pollution within a variety of "real world" nursery school environments, with a focus on reducing key air pollutants (NO_2), and particulate matter (PM_{10} and $PM_{2.5}$), as research shows that young children exposed to these pollutants are more likely to develop lung problems and breathing difficulties such as asthma as they grow up.

1.2.22. The findings of the air quality monitoring have been reviewed, comparing the recorded changes in air quality within the classroom with the AFS versus the control. The analysis also considered the range of criteria associated with the nursery environment.

1.2.23. The intention of this trial has been to determine the general effectiveness and suitability of AFS technologies within a nursery setting, and it is recognised that given each unit has been operating in a different nursery environment, direct comparisons between the performance of the different AFS units are not possible.

1.2.24. Consequently, the supplier's details are anonymised when reporting on each specific site, with the assessments focusing on establishing the effectiveness of each AFS system in its given environment, and then identifying which environmental conditions were found to be most or least conducive, and what features or types of AFS were found to be most/ least effective.

1.2.25. The participating suppliers are profiled within the reporting, including a summary table of some of the key criteria identified in the AFS shortlisting process.

2

AIR FILTRATION SYSTEM RESEARCH AND SHORTLISTING

2 AIR FILTRATION SYSTEM RESEARCH AND SHORTLISTING

2.1 DEFINITION OF AN AFS

2.1.1. An Air Filtration System (AFS) is generally a device that removes or reduces the amount of particles and pollutants within an environment. It operates with the air that passes through it in one or multiple stages. An AFS can be simply a filter, for instance fitted to an air handling unit operating in a mechanically ventilated environment, or a stand-alone unit which helps reduce particulate matter, oxides of nitrogen and other atmospheric pollutants within a confined area. In either case, the filter traps and filters out airborne particles before the air is released into the room. An AFS can also function as an “air purifier” if it is able to sanitise the air by neutralizing airborne toxins.

2.1.2. An AFS differs from an air conditioning system as it does not remove any heat and humidity, or provide cooled air / heated air to the environment. A typical air conditioning unit is primarily designed to cool the environment where it operates. Air conditioning units have some air filtration integrated to the ventilation process, but it is not their primary function.

2.1.3. Although the principle of air filtration is well established and applied within building services in mechanically ventilated buildings, there are still few widely recognised and robust technical standards to readily enable full comparisons of different AFS. This is due to the lack of common regulations specific for stand-alone AFS’s. Whilst single components are widely regulated by standards and certifications, such as HEPA filters, fans, electric motors, electric connection, the stand-alone AFS as a whole has no relevant standards and certifications (apart from CE marking or electric connection), to enable deep comparison of the range type and models on the market. As part of the research reported below, we found there were cases of AFS’s fitted with high efficiency HEPA filters, but which were not able to demonstrate strong documentation and certifications for a properly sealed filtration grid; and as a result, this might impact the AFS removal capacity. As such a single high specification component may not in itself assure the effectiveness of the unit.

Figure 2-1 - Example of filter used in mechanically (left) and naturally ventilated (right) buildings

2.2 AFS TECHNOLOGY TYPES

2.2.1. Air Filtration Systems operate using a range of different technologies (either solely or, more commonly, combined) to remove particulate matters and harmful gases:

- Mechanical filtration: used for removing particulates using physical barriers
- Chemical methods: used for removing harmful gases through chemical reactions
- Ionisation / Electrostatic precipitation: used for removing particulates through electrically charging

2.2.2. A further technology available on the market are “Ozone Generators”, that produce Ozone by design to remove harmful gases and pollutants. These are typically used for the decontamination of biological particles in a laboratory or similar enclosed space while the facility is shut down and vacated, and would not be suitable for use in a live nursery environment, so have not been considered as part of this research and trial.

Mechanical Filtration

2.2.3. Mechanical filtration is the simplest and the most commonly used and established form of filtration, and has been used in engineering for decades. This approach entails trapping air particles in the filter without altering them. High-efficiency particulate arresting (HEPA) filters are often used, capturing up to 99.97% of particles with a size of 0.3 microns. Mechanical filters are designed to remove all airborne pollutants 0.3 microns or larger from the air that passes through the filter itself. Since the filter is mechanical, it does not produce ozone in the process of cleaning the air.

Chemical methods

2.2.4. Carbon activated filters adsorb gases and odours as air passes through them. They use chemical adsorption to remove contaminants and impurities.

2.2.5. HEPA filters can be combined with carbon filters to capture VOCs, eliminate odours and gases in the air. The only limitation is that the carbon filter increases resistance of air flow, dropping the pressure across the air purifier, and hence increasing the required power of the fan motor to overcome this resistance.

2.2.6. In addition, other chemical methods include the use of UV radiation; though not capable of destroying VOCs directly, it can be used to initiate a chemical reaction that may cleave VOC compounds. Air purifiers often use titanium dioxide as a catalyst, which helps to initiate such as a chemical reaction. UV radiation may also kill organisms that are also considered air pollutants, such as moulds, viruses and bacteria.

2.2.7. Carbon Filtration Scrubbing Systems are effective at scrubbing VOCs from ambient air, and removing any residual ozone generated during UV treatment of filtered air through adsorption, and as such are often feature within chemical method type AFS which also use UV treatment.

2.2.8. Concentrations of VOCs can be significantly reduced through carbon filtration, whilst the possibility of ozone discharge from the AFS is removed through the use of carbon filters.

Ionization / Electrostatic precipitation

2.2.9. This process works by adding electrical charge to airborne pollutant particles. These charged particles are attracted and deposited on surfaces. An electrostatic precipitator is used to create ionisation, to charge dust particles which can then be collected on metal plates or filter media, which carry an opposite charge.

2.2.10. Ionization produces small amounts of ozone, which is itself another harmful gas, and so must be eliminated or reduced to nearly zero. Electrostatic precipitators always require a system to eliminate / decrease ozone produced as by-product. Ionisators that work without Ozone control and abatement have not been included in this trial.

2.2.11. Research has demonstrated that activated carbon is effective at removing ozone from the air, and consequently activated carbon filters are often fitted to complement other filtration processes.

2.3 AFS RESEARCH AND SHORTLISTING

2.3.1. Our research into AFS accounted for:

- Technical specifications available on the internet and public sources
- Technical specifications provided by the suppliers
- Discussions with suppliers
- Independent publications

2.3.2. Indoor air filtration comes in two common forms, depending on the site ventilation system configuration:

- Natural ventilation: air filtration systems (AFS) are in the form of stand-alone or wall mounted air cleaners;
- Mechanical ventilation: air filtration systems (AFS) are in the form of filtration at a centralised level via air handling units.

2.3.3. The majority of the 20 audited nurseries have natural ventilation in place; which reflects in part the typical age of the buildings, and their comparatively small size in terms of square meters. As a result, the focus of the research has been towards units that are applicable for naturally ventilated buildings / rooms, rather than systems which function as part of mechanical ventilation systems.

2.3.4. All the AFS assessed deliver a level of particulate removal, however the efficiency of this varies from between each system. Fewer AFS on the market are designed for the effective removal of NO_x. Many AFS also provide abatements in virus, volatile organic contents (VOCs), bacteria and allergens.

2.3.5. The AFS typically take the form of standalone floor-standing or wall-mounted units, though a number of units also required ducting to be installed.

2.3.6. The average lead in time for placing an order for the AFS and the scheduled installation date was typically around 4 weeks. The installation of the units typically required no more than one hour.

2.3.7. As the AFS market is still rapidly evolving and it is not technically regulated worldwide, different countries and continents apply different standards and references. The approach of this research has therefore been to take into consideration the existing certifications of the units on the market, as well as the standards followed within the testing reports for each unit.

2.3.8. The main standards and industry criteria that were taken into consideration as part of the manufacturer / AFS review are summarised below:

CE MARKING

2.3.9. A CE Marking is a certification mark that indicates conformity with health, safety, and environmental protection standards for products sold within the European Economic Area (EEA). The CE marking is also found on products sold outside the EEA that are manufactured in, or designed to be sold in, the EEA.

EUROPEAN STANDARDS FOR HIGH EFFICIENCY PARTICULATE AIR (HEPA) AND ULTRA LOW PENETRATION AIR (ULPA)

2.3.10. The European Union standard for both HEPA and ULPA filters – EN 1822 – classifies filters into different classes depending on their efficiency. All EN 1822 specifications are based on a filter's ability to trap and contain the most penetrating particle size (MPPS) particular to the filter. The MPPS is typically determined by a laser spectrometer or electrostatic classifier.

2.3.11. The HEPA filter classes and relevant specifications are listed in the table below:

Table 2-1 – HEPA Filter Classification and Efficiency

Classification	Filter Type	Percentage Efficiency at MPPS
E10	HEPA	≥85
E11	HEPA	≥95
E12	HEPA	≥99.5
H13	HEPA	≥99.95
H14	HEPA	≥99.995
U15	ULPA	≥99.9995
U16	ULPA	≥99.99995%
U17	ULPA	≥99.999995%

ISO 16890-2016

2.3.12. This defines testing procedures and a classification system for air filters used in general ventilation equipment. This new standard provides the first opportunity for global harmonisation as it proceeds to replace the two existing localized standards; ASHRAE 52.2 which is dominant in USA and EN779:2012 which is dominant in Europe.

ISO 10121-2:2013

2.3.13. It provides "Test methods for assessing the performance of gas-phase air cleaning media and devices for general ventilation — Part 2: Gas-Phase Air Cleaning Devices (GPACD)". Essentially it gives also a test method for NO_2 removal filters.

ANSI/AHAM AC-1

2.3.14. This sets procedures to define Clean Air Delivery Rate (CADR). It is "an indication of the volume of filtered air delivered by a portable air purifier". However, it has some weaknesses.

2.3.15. The following are weaknesses associated with CADR:

- The measurement only applies to particulate matter, not to gases
- The rating is based on a 20-minute test
- It does not account for any decline in effectiveness over time, as the test is only for a short period.
- Some low-efficiency filters employ ionization, which attaches a weak electrostatic charge to particulate matter, which can cause several smaller particles to group together resulting in a lower particle measurement count

- Test carried out on purifiers running on their highest setting. But users will often use lower settings to reduce noise, and this can drastically reduce the efficiency of an air cleaner

2.3.16. An assessment of the AFS available for purchase within the UK was undertaken to identify the most suitable units for trialling in the nurseries. The research was undertaken by contacting manufacturers and suppliers with manufacturing and/ or distribution operations within the UK.

2.3.17. In selecting appropriate AFS systems, the following criteria were taken into consideration:

- Manufacturer capacity and history
- Technical strengths of the unit (filters quality, flow rates, dB)
- Filtration/removal technology
- PM removal efficiency
- NO_x removal efficiency
- Testing results/certification
- Maintenance cost
- Operational cost (energy usage)
- Case studies provided
- Unit Price
- Market availability
- Health & Safety

2.3.18. A weighted assessment matrix was developed to inform the shortlisting process, to account for a range of criteria and rank and compare the AFS units available.

Table 2-2 – AFS Preliminary Shortlisting Assessment Criteria

Capacity	Technical Strengths	NO_x Removal Efficiency	PM Removal Efficiency	Certificates	Maintenance Cost	CAPEX	OPEX	Case Studies
0 - low	0 - none	0 – no removal	0 – extremely low	0 - none	0 – high annual costs	0 – high capex	0 – medium / high energy consumption	0 – none available
1 - medium	1 - low	1 – some	1 – low	1 - none	1 – medium annual costs	1 – medium capex	1 – low energy consumption	1 – very few available
2 - medium	2 - medium	2 – claimed removal	2 – medium	2– more than three	2 – low annual costs	2 – low capex		2 – some available
	3 - high	3 – proved removal evidence	3 - good	3 – many and consistent				3 - many

2.3.19. A shortlist of six AFS suppliers were determined and agreed with the GLA Programme Advisory Group (PAG), with the suppliers then being invited to participate in the trial:

- Camfil
- IQair
- Radic8
- Blueair
- AeraMax Professional (Fellowes Brands)
- Airlabs

2.4 SHORTLISTED AFS TECHNOLOGIES TYPES

2.4.1. The AFS technology types of shortlisted units are summarised in the table below, which also highlights which units generate potentially harmful by-products as part of their cleaning process, and the certification and test results provided by the manufacturers for managing these proceses.

Figure 2-2 - Summary of participating AFS suppliers technnology types and ozone mitigation

AFS		CAMFIL	IQAIR	BLUEAIR	RADIC8	AIRLABS	FELLOWES
Technology Type	PM Filter	X	X	X	X	X	X
	Carbon Filter	X	X	X	X	X	X
	UV				X		
	Titanium Dioxide Activated				X		
	Electrostatic/Ionisation			X		X	X
Ozone utilised in air filtration process		N	N	Y	Y	Y	Y
Ozone trapped/ eliminated in filtration system		N/A	N/A	Y	Y	Y	Y
Ozone test results provided		N	N	N	Y (<0.001 ppm)	Y (98% reduction)	Y (<4 ppm)
Independent accreditations of safe Ozone levels		N/A	California Air Resources Board	California Air Resources Board			California Air Resources Board
		N/A	N/A		Korean K-BPR	Copenhagen University Publication	Underwriter Laboratories

2.4.2. The potentially harmful by-products include ozone and hydroxyl radicals:

Ozone

2.4.3. Ozone produced by electrostatic precipitators and ionization, or during UV treatment of filtered air, must be eliminated or reduced to nearly zero. Research has demonstrated that activated carbon is effective at removing ozone from the air, and consequently activated carbon filters are often fitted to complement other filtration processes.

Hydroxyl Radicals

2.4.4. Hydroxyl radicals used within the air cleaning process in some chemical method AFS's are also potentially harmful if not properly contained within the unit, so were also considered as part of this trial.

2.4.5. Hydroxyls are also formed in nature in our lower atmosphere, predominantly by the photolytic decomposition of ozone by UV radiation at about 315 nm, to yield concentrations of about one to ten million molecules per cubic centimetre outdoors[6][7].

2.4.6. Atmospheric hydroxyls do not exist naturally indoors at levels high enough to sanitize. Hydroxyl cleansing systems work by irradiating the water vapor and other gases in air as it is circulated through chambers equipped with quartz lamps (also called optics), generating hydroxyls and other oxidants. Ideally, they do so by producing concentrations similar to those found in nature. Hydroxyl formation rates vary widely with the type and number of lamps used and relative humidity.

2.4.7. As a category, the US Federal Drug Agency and other regulatory agencies do not currently regulate or require pre-market approval for UV air and surface cleaning devices, because they irradiate ambient air and sanitize in a manner similar to that found in nature.

2.4.8. They do require that the devices prove they do what they claim and comply with Occupational Safety and Health Agency (OSHA) industrial safety standards. To do so, manufacturers of sanitizing systems should provide scientific data for efficacy and safety, although this is not often done since non-regulated devices are rarely challenged by government regulatory agencies.

Shortlisted AFS technology types and ozone production

2.4.9. As described in Section 2.2, mechanical filtration devices using only PM filters (HEPA and carbon activated filters) do not produce ozone or radicals, so require no ozone mitigation measures.

2.4.10. The IQair and Camfil systems do not report using electrostatic precipitators, ionisation or UV lights, so would not produce ozone.

2.4.11. The Radic8, Blueair, Airlabs and AeraMax Professional AFS units all produce ozone during some stages of their operation; however, all of them are designed to trap the ozone produced as by-product in their cleaning processes. Consequently, for these units the ozone test results and independent accreditations were scrutinised.

2.4.12. The Blueair, AeraMax Professional and IQair AFS are all certified as ozone free manufacturers by the California Air Resources Board (CARB), a widely respected institution within the industry.

2.4.13. Radic8 supplied ozone testing results, whilst AeraMax Professional publish their testing results on their website. Airlabs is supported by independent testing and accreditation by Copenhagen University.

2.4.14. There are currently no mandatory EU/UK specific regulations that strictly apply to Air Filtration Systems in terms of ozone testing / emissions (apart from the general air pollutants regulations).

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[6] D. E. Heard, Ed. "Analytical Techniques for Atmospheric Measurement", Blackwell Publishing, Ltd., (2006)
[7] D. R. Crosley, The Measurement of OH and HO2 in the Atmosphere, J. Atm. Sci. 52, 3299 (1995)

There are also no common testing standards for AFS in terms of formaldehyde. As such, further independent testing in the UK/Europe would be beneficial in providing additional confirmation.

2.4.15. Based on our assessment of the technologies deployed, the specifications of the units and test results and certifications made available, the shortlisted units do not pose a risk in terms of ozone in a general nursery environment.

2.4.16. According to the information provided by the suppliers, there is no formaldehyde release from the units selected for the trial. In the case of the Radic8 unit, very low levels are released, but are subsequently cleaned by the filtration system, resulting in a net improvement within the room.

2.5 SHORTLISTED AFS UNIT SUPPLIERS

2.5.1. This section reports the main specifications in terms of filtration type, capacity, energy consumption and components of the shortlisted suppliers.

2.5.2. A full list of data sheets, laboratory testing and case studies provided can be found in the Appendix.

CAMFIL

2.5.3. Camfil is a global manufacturer operating in clean air solutions providing commercial and industrial systems for air filtration and air pollution control. The group was founded in Sweden in 1963, it has 4,480 employees around the world and an annual turnover in the region of £700m. It is also well established in the UK air filtration market, and offers a wide range of solutions for indoor air quality.

2.5.4. The Camfil unit uses mechanical particulate filtration and molecular carbon filtration, and does not operate using the same method as those using chemical bonding to remove NO_x. As a result, there is no production of ozone or acidic aggressive gases. The type of molecular gas filtration offered by Camfil uses activated carbon medium for NO_2 removal.

2.5.5. The processes of adsorption and chemisorption present are not hazardous to human health. It is used in conjunction with particle filters to remove the PM_{10} fine combustion particles present in air from burning of fossil fuels.

2.5.6. As a result, there is no production of Ozone and/or hydroxyl radicals. The Camfil unit does not use any filtration technologies such as electrostatic precipitators, UV lights, ionisers.

2.5.7. Although we assessed all the Camfil AFS available on the market, the most suitable units for a nursery environment is reported in Table 2.3. This unit has different sizes depending on the size of the room.

Table 2-3 – Camfil AFS Details

Camfil	
Removal capacity	Particulate (floor standing or wall mounted unit)
	Particulate + NO_x (optional extra)
Filters	HEPA + carbon activated (as option)
Capacity	Air Cleaner CC400: 0-410 m^3/h (wall mounted system)
Maintenance (filters life span)	8-9 months (floor standing)
	1 year (wall mounted) - circa £350
Energy consumption	£13-60 per year
Cost to supply	Circa £800 (floor standing unit – up to 45 m^2)
	Circa £1,800 (wall mounted system – up to 120 m^2)

Figure 2-3 - Camfil wall mounted AFS Air Cleaner CC with detail of molecular filter

2.5.8. The removal efficiency of these units is supported by a list of tests carried out according to ISO standards. NO_x abatement is optional but can be fitted to the units. The documentation provided by Camfil included:

- Technical specifications
- Data sheets

IQAIR

2.5.9. IQAir is a Swiss manufacturer operating since 1963. It operates mainly in the indoor air quality field, and in the UK it is marketed via accredited distributors.

2.5.10. The IQAir system only uses leakage free HEPA filtration, hence mechanical filtration, which does not produce any by-products and are 100% ozone free.

2.5.11. The IQAir AFS can be equipped with gas filtration, but for this trial a mechanical filtration only device was deployed, and this is confirmed by the Certified Air Cleaning Devices list of CARB (California Air Resources Board).

2.5.12. Although we assessed all the IQAir AFS available on the market, the most suitable unit for a nursery environment is reported in the table below. This unit has different sizes depending on the size of the room.

Table 2-4 – IQAir AFS Details

IQAir	IQAir
Removal capacity	Particulate + mould spores, bacteria, viruses
Filters	Pre-filter + HEPA filter + odour/gas filter
Capacity	Up to 70-80 m² - 50-440 m³/h
Maintenance (filters life span)	HEPA filter: circa 4,300 hours (£130)
	Carbon filter: hours not disclosed (£118)
Energy consumption	Circa £63 per year
Cost to supply	Circa £1,400 if wall installation and air ducting needed

Figure 2-4 - IQair AFS CleanZone SL

2.5.13. This AFS has a strong configuration for particulate abatement (pre-filter + HEPA filter + odour filter); however, it does not remove NO_X if installed without gas filtration. The documentation provided by IQAir included:

- Technical specifications
- Data sheets
- Testing results
- Case studies

RADIC8

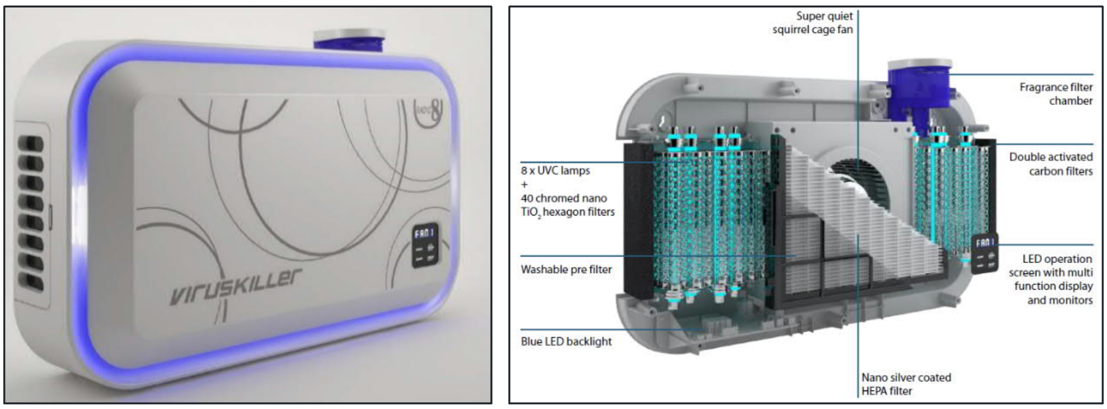
2.5.14. Radic8 is a British company that distribute air purifiers manufactured by a South Korean partner. It has been operating in the UK market since 2012.

2.5.15. The Radic8 units use a combined approach, made of:

- PM filter (Mechanical filtration)
- Carbon activated filter (Chemical methods)
- UV lights (Chemical methods)

2.5.16. This combined technology made of mechanical filtration (pre-filter + HEPA) for particulate matters, UV lights & Titanium dioxide catalyst to remove VOCs and kill viruses and bacteria and a carbon activated medium to absorb Ozone and Hydroxyl that are created. Based on the test report provided the ozone emission concentration is < 0.005 µmol/mol (ppm). As a result, it can be used in an environment where there are people.

Figure 2-5 - Radic8 AFS VK Blue



2.5.17. Based on the material provided, the applied technology should be able to guarantee safe operation.

2.5.18. The Radic8 system uses UV lamps in a matrix of titanium dioxide filters to create a chamber full of UV-C sterilisation and photocatalytic oxidation. As such, TiO2 is not a by-product; rather is used as a component of the unit. This is because of its resistance to ultraviolet UV light in exposed applications.

2.5.19. Radic8 provided testing results ("MRSA Test Results from Korea Test Institute KTL) for formaldehyde using Test Method KOA AS 01, which is the test standard for the Korea Air Sterilizer Association. The unit was found to achieve a 95% removal rate for formaldehyde over 120 minutes.

Airborne Bacteria Removal Rate		**80% over**	**96.3 %**	**99.1%**	**99.4%**	60 min
Harmful Gas Deodorization Rate	Ammonia	30% over	63%	81%	79%	120 min
	Acetic Acid	30% over	100%	100%	100%	
	Toluene	30% over	100%	100%	100%	
	Acetaldehyde	30% over	88%	100%	100%	
	Formaldehyde	30% over	71%	82%	95%	

2.5.20. Radic8 also provided the test results of release levels from the units, which are under the Korean Air Cleaning Association minimum levels (VK Blue is the unit installed at the nursery – 0.184 < 1.8 mg/hour).

Figure 2-6 - Radic8 Tests results

Description		Limit of KOA AS 01	Test Results of VIRUSKILLERS			Remarks
			VK-BLUE	VK-001 and VK-002	VK-102 and VK-102	
Release of Harmful Substances	Particulate matter	4.0 under	0.052	0.083	0.083	mg/hr
	TVOC's	18.0 under	0.276	0.088	0.088	
	Acetaldehyde	1.8 under	0.037	0.024	0.024	
	Formaldehyde	1.8 under	0.184	0.063	0.063	

2.5.21. Although we assessed all the Radic8 AFS available on the market, the most suitable unit for a nursery environment is reported in Table 2.5. This unit has different sizes depending on the size of the room.

Table 2-5 – Radic8 AFS Details

Radic8	RADIC8
Removal capacity	Particulate + NO_x + various bacillus and fungus
Filters	HEPA + titanium dioxide filter
Capacity	VK Blue model: up to 60 m² - 120-240 m³/h
Maintenance (filters life span)	HEPA filter: 2,000 hours (£80)
	Carbon filter: 8,000 hours (not disclosed)
Energy consumption	Circa £33 (VK Blue) per year
Cost to supply	£1,000 retail price
	Circa £700 if purchased directly

2.5.22. This AFS claims to reduce various bacillus and fungus, in addition to PM and NO_x, which is a wider benefit of the unit. The documentation provided by Radic8 included:

- Technical specifications
- Data sheets
- Testing results
- Case studies

BLUEAIR

2.5.23. Blueair is a Swedish manufacturer that has been working in the indoor air quality sector for two decades. Blueair has been a member of the Unilever family of brands since 2016.

2.5.24. The Blueair units use a combination of filtration approaches:

- PM filter (Mechanical filtration)
- Carbon activated filter (Chemical methods)
- Electrostatic - Ionisation (Ionisation)

2.5.25. Blueair AFS technology uses an ionisation process inside the unit during operation. This system uses a very low electrical current to minimise ozone production and a sealed steel housing surrounding the ionization chamber to keep ozone contained. For more protection, the activated carbon filter adsorbs ozone particles that may escape from the encapsulated ionisation chamber.

2.5.26. This unit has been tested according to the most stringent test for ozone used in ETL/UL testing, and conforms with tests that the California Air Resources Board demands in order to be able to sell an air purifier in California. Tests are undertaken to establish the maximum ozone emission of the unit, so they test with and without filters, and on all operating settings, short and long time etc, and report the maximum emissions. In order to meet test requirements an ozone concentration less than 50 ppb is required. All Blueair models are reported to achieve less than < 1 ppb.

2.5.27. Based on the material provided the applied technology meets safe AFS operation. Blueair provided additional ozone testing results carried out at the SP Technical Research Institute of Sweden.

2.5.28. Although we assessed all the Blueair AFS available on the market, the most suitable units for a nursery environment is reported in Table 2.6 This unit has different sizes depending on the size of the room.

Table 2-6 – Blueair AFS Details

Blueair	Blueair
Removal capacity	Particulate + NO_x
Filters	HEPA + carbon activated filter
Capacity	Classic 605: up to 72 m^2 - and 850 m^3/h
Maintenance (filters life span)	HEPA filter: circa 4,300 hours (£99)
	Carbon filter: hours not disclosed (£150)

Energy consumption	Circa £60 per year
Cost to supply	£800 retail price

Figure 2-7 - Blueair AFS "Classic 605"

2.5.29. This AFS has a hybrid configuration which uses mechanical filtration, ionisation and carbon activated filters to remove PM and NO_x. It can be deployed as a free-standing or wall mounted unit.

2.5.30. The documentation provided by Blueair included:

- Technical specifications
- Data sheets
- Testing results
- Case studies

AERAMAX PROFESSIONAL (FELLOWES BRANDS)

2.5.31. Fellowes Brands is a manufacturer of office and technology accessories. Fellowes Brands owns and operates 17 subsidiaries worldwide and employs more than 1,500 people throughout the world. Fellowes launched their AeraMax Professional (Fellowes Brands) air purifiers in 2013.

2.5.32. The AeraMax Professional (Fellowes Brands) units use a combination of filtration approaches:

- PM filter (Mechanical filtration)
- Carbon activated filter (Chemical methods)
- Ionisation

2.5.33. The AeraMax Professional (Fellowes Brands) units produce ozone as by-product of its ionisation process, which is then trapped by an activated carbon filter.

2.5.34. Underwriter Laboratories commissioned by Fellowes conducted UL 867 testing procedures to determine the level of ozone by-product generation by the PlasmaTRUE™ bipolar ioniser used in AeraMax Professional purifiers. The highest level of ozone generation observed during testing was 4.0 ppb (acceptable level for ozone is up to 50.0 ppb).

2.5.35. Based on the material provided the applied technology meets safe AFS operation.

2.5.36. Although we assessed all the AeraMax Professional (Fellowes Brands) AFS available on the market, the most suitable units for a nursery environment is reported in Table 2.7. This unit has different sizes depending on the size of the room.

Table 2-7 – AeraMax Professional (Fellowes Brands) AFS Details

AeraMax Professional (Fellowes Brands)	Fellowes
Removal capacity	Particulate + mould spores, bacteria, viruses
	NO_x (some models in Hybrid set up)
Filters	Pre-filter + HEPA filter + odour/gas filter
Capacity	Up to 130 m² - up to 747 m³/h
Maintenance (filters life span)	HEPA filter: ~£100 (every 12 months)
	Carbon filter: ~£50 (every 6 months)
Energy consumption	Circa £100 per year
Cost to supply	Circa £1,200 retail price

Figure 2-8 - AeraMax Professional (Fellowes Brands) AFS

2.5.37. This AFS has a hybrid configuration which uses mechanical filtration, ionisation and carbon activated filters to remove PM and NO_x.

2.5.38. The documentation provided by AeraMax Professional included:

- Technical specifications
- Data sheets
- Testing results
- Case studies

AIRLABS

2.5.39. Airlabs is an emerging British-Danish company that specialises in air filtration, and recently launched its stand-alone AFS for indoor environment, based on the Airlabs in-vehicle air cleaning technology. Their background is mainly in transport based air cleaning.

2.5.40. The Airlabs units use a combined approach, including:

- PM filter (Mechanical filtration)
- Carbon activated filter (Chemical methods)
- Electrostatic precipitator (Ionisation)

2.5.41. Their indoor air cleaner is designed to provide clean air, free of particles and toxic gases to a wide range of environments, including nurseries. The unit can be operated directly or via infrared remote control.

2.5.42. The Airlabs system uses an electrostatic precipitator (ESP) to remove the particles and then a nano-carbon filter to clean the gases. ESPs are known to produce a small amount of ozone because of the high voltage used to charge the particles. However, this ozone is reported to be entirely removed by the nano-carbon filter, which reduces ozone levels to below ambient.

The nano-carbon filter also traps hydrogen peroxide, should any be produced. Trace amounts of radicals may be produced by the ESP; however, these are reported to be also completely absorbed by the nano-carbon filter. This is supported by prior research and information provided by Airlabs concerning removal capacity.

PERFORMANCE

	NO_2	OZONE	VOCs	SO_2
Removal efficiency[1] /%	95	98	60	71

[1] At lowest speed.

2.5.43. Airlabs report a 98% ozone removal (including the ozone in the environment) which means the ozone produced by the unit is negligible.

2.5.44. Based on the material provided the applied technology meets safe AFS operation.

Table 2-8 – Airlabs AFS Details

Airlabs	airlabs
Removal capacity	Particulate + NO_x
Filters	PM + Carbon activated
Capacity	300 – 1,200 m³/h
Maintenance (filters life span)	Filters replacement indicated every 6 months at a cost of circa £400 per year
Energy consumption	Circa £70 per year
Cost to supply	Circa £1,800

Figure 2-9 - Airlabs AFS "Airbubbl"

2.5.45. This AFS has a hybrid configuration uses mechanical filtration, ionisation and carbon activated filters to remove PM and NO_x. Their AFS has been recently launched, so is a new entrant onto the marketplace. Their independent accreditation is provided by the University of Copenhagen.

2.5.46. The documentation provided by Airlabs included:

- Technical specifications
- Data sheets
- Testing results
- Case studies

3

NURSERY SELECTION AND BASELINE AIR QUALITY

3 NURSERY SELECTION AND BASELINE AIR QUALITY

3.1 NURSERIES SELECTION

3.1.1. The six participating nurseries were selected using an evidence based approach, which included the findings of the air quality audit assessments, informed by site visits, air quality monitoring, both in and around the nursery, and modelled air quality data.

3.1.2. A multi-criteria assessment matrix was developed for selecting the nurseries to ensure a fair and transparent process was in place, featuring the following assessment criteria:

Key Criteria

- Air quality monitoring: based on short term NO_2 measurements at each site;
- Modelled air quality concentrations near the nurseries: based on modelled annual mean NO_2, PM_{10}, $PM_{2.5}$ levels taken from the 2013 London Atmospheric Emissions Inventory; and
- Air Quality Audit observations and recommendations: based on site visits, including the exposure of children to poor indoor air quality, the suitability of the nursery for an AFS, the support of the nursery staff and borough officers for an AFS, and preliminary recommendations having been made for AFS to be considered.

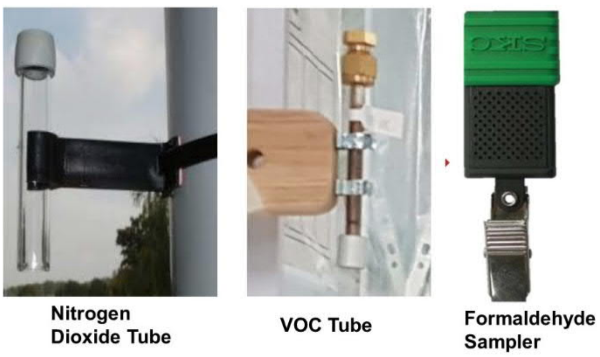
Secondary Criteria

- Number of children on roll: prioritising nurseries where more children are affected.
- Geographic spread of nurseries – achieving a mix of central/ inner and north/ east/ south/ west, where possible.
- Building types – featuring a range of building ages, construction types, natural / mechanical ventilation, where possible.
- Proximity to emission sources/ types – seeking a range of local environments and pollution climates where possible.
- Health inequalities/ borough participation in the Mayor's Healthy Early Years London programme.

3.1.3. A 3-month baseline air quality survey was undertaken to monitor Nitrogen Dioxide (NO_2), Formaldehyde and Volatile Organic Compounds (VOCs) at sites both inside and outside the nursery building, in order to capture any attenuating influence the indoor environment may have on NO_2 concentrations.

3.1.4. Nitrogen Dioxide is a secondary pollutant, derived from emissions of nitrogen oxides (NO_x) from combustion sources. In London key sources include road vehicles and domestic boilers. Vehicle emissions contribute significantly to local increases in concentrations especially near busy roads.

Figure 3-1 - Baseline Air Quality Monitoring Equipment



3.1.5. VOCs are made up of a range of organic compounds, including formaldehyde. They have a significant photochemical oxidant forming potential and contribute to the formation of secondary pollutants, such as

NO_2. They arise from a wide variety of products commonly used in homes and workplaces, including furnishing, carpets, upholstery, cleaning products and air fresheners.

3.1.6. Formaldehyde is a notable VOC, and can be released from furniture, finishes and building materials, and is formed in chemical reactions from combustion processes, such as smoking, heating, cooking or candle burning.

AIR QUALITY STANDARDS AND OBJECTIVES

3.1.7. The relevant ambient (outdoor) air quality strategy objectives and standards for NO_2 and particulate matter (PM_{10} and $PM_{2.5}$) are given in Table 3-1. The air quality standards are levels recommended by the Expert Panel on Air Quality Standards (EPAQS) and the World Health Organisation (WHO) and are based on current scientific knowledge about the effects of each pollutant on health and the environment.

Table 3-1 - UK Air Quality Strategy Objectives for NO_2 and Particulate Matter ($PM_{2.5}$ and PM_{10})

National Air Quality Objectives and EU Limit Values for the Protection of Human Health

Pollutant	Applies to	Objective	Measured as	Date to be achieved by and maintained thereafter	European Obligations	Date to be achieved by and maintained thereafter
Nitrogen dioxide (NO_2)	UK - Outside	200µg/m^3 (not to be exceeded more than 18 times a year)	1-hour mean	31.12.2005	200µg/m^3 (not to be exceeded more than 18 times a year)	01.01.2010
	UK - Outside	40µg/m^3	Annual mean	31.12.2005	40µg/m^3	01.01.2010
Particulate Matter (PM_{10}) (gravimetric)†	UK - Outside (except Scotland)	40µg/m^3	Annual mean	31.12.2004	40µg/m^3	01.01.2005
	UK - Outside (except Scotland)	50µg/m^3 (not to be exceeded more than 35 times a year)	24-hour mean	31.12.2004	50µg/m^3 (not to be exceeded more than 35 times a year)	01.01.2005
Particulate Matter ($PM_{2.5}$)	UK - Outside (except Scotland)	25µg/m^3	Annual mean	2020	Target value 25µg/m^3	2010

Ozone (O_3)	UK	100 µg/m^3 (not to be exceeded more than 10 times a year)	8-hour mean	31.12.2005	Target of 120 µg/m^3 (not to be exceeded by more than 25 times a year averaged over 3 years)	31.12.2010

† Measured using the European gravimetric transfer sampler or equivalent.
µg/m^3 = microgram per cubic metre.

3.1.8. There are both long-term (annual mean) and short-term standards. In the case of NO_2, the short-term standard is for a 1-hour averaging period, whereas for PM_{10} it is for a 24-hour averaging period. These periods reflect the varying impacts on health of differing exposures to pollutants, for example temporary exposure on the pavement adjacent to a busy road, compared with the exposure of residential properties adjacent to a road.

3.1.9. Air quality at places of work are expected to achieve airborne pollutant concentrations which are well below workplace exposure limits (WELs). These concentrations are set out in the document EH40[8], and contained in Table 3-2 below, take account of the fourth Indicative Occupational Exposure Limit Values (IOELV) Directive (European Directive 2017/164/EU)[9]. WELs are considerably higher than ambient air quality limits. This is in part due to the assumption that occupational exposure periods are assumed to be shorter than the periods of exposure for ambient air. To account for short intense exposures that can occur over a working day, there are two WELs, one for the 8 hr working day, and another higher exposure value applicable to 15 minute exposure periods.

Table 3-2 - Workplace exposure limits (WELs) for places of work in the UK (EH40/2005)

Pollutant	Applies to	Workplace exposure limit	Measured as
Nitrogen dioxide (NO_2)	UK – Place of Work	960 micrograms per m^3	8-hour mean
	UK – Place of Work	1,910 micrograms per m^3	15 min mean
Inhalable Particulate Matter (gravimetric)†	UK – Place of Work)	10,000µg/m^3	8-hour mean
	UK – Place of Work)	20,000µg/m^3	15 min mean

[8] EH40/2005 Workplace exposure limits (https://books.hse.gov.uk/)
[9] Commission Directive 2017/164/EU ‘Establishing a fourth list of indicative occupational exposure limit values’ Official Journal of the European Union 2017

Respirable Particulate Matter	UK – Place of Work	4,000µg/m^3	8-hour mean
Ozone	UK – Place of Work	400µg/m^3	15 min mean
Formaldehyde	UK – Place of Work	2,500µg/m^3	8-hour mean
	UK – Place of Work	2,500µg/m^3	15 min mean

BASELINE NO_2 SURVEY

3.1.10. Prior to the AFS trial, an initial baseline air pollutant survey was undertaken for three months. At each of the twenty nursery schools throughout London from December 2018 to March 2019. Five NO_2 diffusion tubes, one formaldehyde diffusion tube and one VOC diffusion tube were deployed in the following locations:

- Nitrogen Dioxide (NO_2)
  - roadside outside the nursery
  - immediately outside the nursery entrance
  - playground
  - immediately inside the nursery entrance
  - inside a nursery classroom.
- Formaldehyde and VOCs
  - Inside a nursery classroom.

3.1.11. Raw (non-bias adjusted) NO_2 baseline monitoring data results are given in Appendix H. This provided a measure of the air quality at external and internal locations across the nursery site.

3.1.12. Diffusion tubes are passive samplers providing time-integrated, i.e., a month, measure of ambient NO_2 concentrations. As a passive sampler, there is no active sampling device, such as a pump, which would potentially distract children or disrupt classes, thereby limiting the potential interference to with the normal nursery routine - this was identified as a potential risk during the monitoring phase design.

3.1.13. Baseline NO_2 survey concentration data and additional background air quality data was used to select the six nominated nurseries for inclusion in the AFS trial. Further NO_2 diffusion tube monitoring was conducted as part of AFS trial; however, it was not always possible to install diffusion tubes in the same classrooms that had previously been used in the baseline NO_2 survey.

Findings of Baseline Monitoring

3.1.14. The baseline air quality results, and specifically the indoor air quality monitoring results in the classroom, were given a significant weighting (65%) in determining which nurseries were selected for the trial.

3.1.15. At the time the nurseries were being selected for the AFS trial, 1-2 months of baseline air quality monitoring data was available to inform the assessments. As such it is noted that this provided only a snap-shot of concentrations in and around the nursery across the winter and spring months, when concentrations are likely to be at their highest due to elevated NO_x emissions driven by the cold weather.

3.1.16. Roadside NO_2 concentrations were found to be highest at Pembury House in Haringey (70.67µg/m^3), with local road traffic emissions contributing significantly.

3.1.17. Playground NO_2 concentrations were highest in Tachbrook Nursery in Westminster (44.46µg/m^3). At the nursery entrance (outside) concentrations were highest at Pembury House (45.07µg/m^3).

3.1.18. Inside the nurseries, concentrations at the nursery entrances were highest at Colombia Market in Tower Hamlets (33.04µg/m^3), and in the classroom at Colombia Market (34.57µg/m^3). It should be noted that indoor NO_2 is not regulated against EU limits, it is regulated against HSE exposure limits.

Modelled Air Quality Concentrations

3.1.19. In addition to the monitoring undertaken at the site, 2013 baseline annual mean NO_2, PM_{10} and $PM_{2.5}$ concentrations have been estimated for each nursery from the London Atmospheric Emissions Inventory (LAEI) maps. The LAEI model provides mapped annual mean NO_x, NO_2, PM_{10} and $PM_{2.5}$ concentrations on a 20m x 20m basis for the whole of London from a base-year of 2013 for 2020, 2025 and 2030.

3.1.20. The LAEI uses air pollution emission estimates from a wide range of sources including transport, industrial, domestic and commercial combustion, agriculture and long-range transport using the most up-to-date activity data, emission factors and projection factors. The averaged emissions for NO_2, PM_{10} and $PM_{2.5}$ were accorded 10% of the weighting when prioritising nurseries for the trial.

3.1.21. The LAEI baseline annual mean NO_2 and PM_{10} concentrations were highest at Tachbrook Nursery in Westminster (49.70 and 28.00 respectively). $PM_{2.5}$ concentration are highest at Thomas Coram Nursery in Camden. The modelled NO_2 contours reflected pollution gradient changes, with distance, away from the heavily trafficked roads and other key sources around each nursery. PM_{10} and $PM_{2.5}$ sources are much more universal and dispersed than NO_2 sources. A proportion of $PM_{2.5}$ and PM_{10} is imported via weather events from regions outside of London, with other contributions coming from combustion processes, cleaning street sweeping/ dust re-entrainment, construction dust, etc. Therefore, concentration profiles of PM_{10} and $PM_{2.5}$ are less defined than for NO_2.

Air Quality Audit Provisional Recommendations for AFS

3.1.22. A further consideration in identifying nurseries for the AFS trial was whether the air quality audits already completed had resulted in a preliminary recommendation that AFS be considered. These recommendations accounted for the likely exposure of children to poor indoor air quality, the suitability of the nursery building, and the support of the nursery staff.

Other criteria for shortlisting nurseries

3.1.23. The number of children at each nursery was also considered, with 5% of the weighting was ascribed to this criterion. Kintore Nursery in Southwark, with 262 children on the roll, received the highest score against this criteria. Triangle Nursery in Lambeth with 49 children received the lowest score.

3.1.24. The trial sought to engage with a range of boroughs, and so a 5% weighting was awarded to the highest scoring nursery within each borough.

3.1.25. The trial also sought to prioritise nurseries with higher levels of deprivation, and so a 5% weighting was applied, with 4 nurseries awarded the highest score based on their relatively high levels of deprivation.

3.1.26. Participation in the Mayor’s Healthy Early Years London programme was recognised with a 2.5% weighting, and a mix of sites within the Ultra-low Emission Zone (ULEZ) and outside the ULEZ was also prioritised, with the highest scoring sites in the ULEZ and outside the ULEZ each awarded a further 2.5% of the weighing.

Figure 3-2 – Nurser y Prioritisation for AFS Trial

Nursery	Key Assessment Criteria								Secondary Criteria												Prioritisation	
Nursery	Highest Indoor Air NO2 Recorded In Month 1 or 2	Weighted Score (Max) 65	Modelled Air Quality Concentrations: LAEI Modelled Emissions NO2	LAEI Modelled Emissions PM10	LAEI Modelled Emissions PM2.5	Weighted Score (Max) 10	Audit Findings and Provisional Recommendation	Weighted Score (Max) 5	Number of Children	Weighted Score (Max) 5	Geographic Spread: Borough	Weighted Score (Max) - Highest per borough 5	Building Type - Ventilation	Deprivation Score	Weighted Score (Max) 5	Mayor's Healthy Early Years London Programme?	Weighted Score (Max) 2.5	Nursery within ULEZ: ULEZ (2019-21)	ULEZ (Oct 2021 onwards)	Weighted Score (Max) - Highest per ULEZ and non-ULEZ 2.5	Weighted Score (Max) 100	Rank
Columbia Market Nursery School	34.57	65.00	46.80	27.40	17.30	9.60	Maybe	3	81	1.5	Tower Hamlets	5.00	Natural Vent.	1	5.0	Yes	2.50		ULEZ (Oct 2021 onwards)	2.50	94.15	1
Rachel McMillan Nursery School and Children's Centre	28.66	53.89	44.10	26.70	16.80	9.19	Maybe	3	147	2.8	Greenwich	5.00	Natural Vent.	4	3.3	Yes	2.50		ULEZ (Oct 2021 onwards)		79.72	2
Nell Gwynn Nursery School	29.03	54.58	44.60	26.60	16.70	9.22	Maybe	3	164	3.1	Southwark	5.00	Natural Vent.	2	4.4	-			ULEZ (Oct 2021 onwards)		79.38	3
Pembury House Nursery School	26.24	49.34	44.20	25.90	16.10	9.05	Yes	5	173	3.3	Haringey	5.00	Natural Vent.	2	4.4	Yes	2.50		ULEZ (Oct 2021 onwards)		78.63	4
Thomas Coram Centre	26.10	49.07	44.70	27.40	17.70	9.42	No	0	123	2.3	Camden	5.00	Natural Vent.	5	2.8	-		ULEZ (2019-21)		2.50	71.12	5
Dorothy Gardner Centre	25.34	47.65	41.90	26.30	16.60	8.90	Maybe	3	103	2.0	Westminster	5.00	Natural Vent.	2	4.4	-			ULEZ (Oct 2021 onwards)		70.95	6
Ann Bernadt Nursery School	26.33	49.51	39.80	25.90	16.50	8.63	Maybe	3	128	2.4	Southwark		Natural Vent.	2	4.4	-			ULEZ (Oct 2021 onwards)		68.02	7
Golborne Children's Centre	20.71	38.94	41.90	26.30	16.70	8.91	Yes	5	62	2.4	Kensington and Chelsea	5.00	Natural Vent.	1	5.0	Yes	2.50		ULEZ (Oct 2021 onwards)		67.79	8
Robert Owen Nursery School	25.34	47.65	38.30	25.70	16.40	8.44	Maybe	3	249	4.8	Greenwich		Natural Vent.	6	2.2	-			ULEZ (Oct 2021 onwards)		66.06	9
Maxilla Nursery School	20.31	38.19	44.00	26.60	16.90	9.18	Yes	5	62	1.2	Kensington and Chelsea	5.00	Natural Vent.	1	5.0	Yes	2.50		ULEZ (Oct 2021 onwards)		66.05	10
Kintore Way Nursery School and Children's Centre	21.96	41.29	43.00	26.70	17.00	9.10	Maybe	3	262	5.0	Southwark		Natural Vent.	3	3.9	Yes	2.50		ULEZ (Oct 2021 onwards)		64.78	11
Clyde Nursery School	20.74	39.00	40.50	26.10	16.50	8.72	No	0	134	2.6	Lewisham	5.00	Natural Vent.	1	5.0	Yes	2.50		ULEZ (Oct 2021 onwards)		62.77	12
Sheringham Nursery School & Children's Centre	18.92	35.57	39.40	25.80	16.20	8.54	Maybe	3	188	3.6	Newham	5.00	Natural Vent.	2	4.4	Yes	2.50		ULEZ (Oct 2021 onwards)		62.65	13
Triangle Nursery School	21.03	39.54	40.60	26.00	16.50	8.72	No	0	47	0.9	Lambeth	5.00	Natural Vent.	2	4.4	-			ULEZ (Oct 2021 onwards)		58.60	14
Windham Nursery School	21.33	40.11	38.80	25.60	16.00	8.44	No	0	108	2.1	Richmond upon Thames	5.00	Natural Vent.	9	0.6	-		-	-		56.16	15
Somerset Nursery School and Children's Centre	16.58	31.17	40.70	26.30	16.70	8.78	Yes	5	82	1.6	Wandsworth	5.00	Natural Vent.	6	2.2	-			ULEZ (Oct 2021 onwards)		53.74	16
Kay Rowe Nursery School	18.74	35.24	38.10	25.30	16.10	8.34	Maybe	3	128	2.4	Newham		Natural Vent.	2	4.4	-			ULEZ (Oct 2021 onwards)		53.47	17
Alice Model Nursery School	15.38	28.92	46.30	27.30	17.10	9.52	No	0	65	1.2	Tower Hamlets		Natural Vent.	2	4.4	Yes	2.50		ULEZ (Oct 2021 onwards)		46.62	18
Ethelred Nursery School and Children's Centre	16.74	31.48	46.00	27.20	17.20	9.49	No	0	60	1.1	Lambeth		Mechanical	5	2.8	-		ULEZ (2019-21)			44.88	19
Tachbrook Nursery School	10.44	19.63	49.70	28.00	17.60	10.00	Yes	5	52	1.0	Westminster		Natural Vent.	4	3.3	-			ULEZ (Oct 2021 onwards)		38.96	20

Note: Classrooms unless samples where not available, in which case Nursery Entrance (inside) readings were used.
Most of the nurseries had two months data collected and analysed at the time of determining which should be selected for the AFS trial, with the exception of Somerset. Dorothy Gardner, Windham, Rachel McMillan and Thomas Coram

3.1.27. Based on the detailed prioritisation criteria and evidence based assessment outlined over the preceding pages, the six participating nurseries were selected as follows:

- Columbia Market Nursery School (Tower Hamlets)
- Rachel McMillan Nursery School and Children's Centre (Greenwich)
- Nell Gwynn Nursery School (Southwark)
- Pembury House Nursery School (Haringey)
- Thomas Coram Centre (Camden)
- Dorothy Gardner Centre (Westminster)

3.1.28. From this point on they will be referred to in short form as:

- Columbia Market
- Rachel McMillan
- Nell Gwynn
- Pembury House
- Thomas Coram
- Dorothy Gardner

3.1.29. The Table below presents the findings of the 3-month average baseline air quality monitoring for the selected nurseries, alongside LAEI 2013 modelled concentrations for the site:

Table 3-3 – Average Concentration Results from Three Month Nursery Baseline Air Quality Monitoring

Nursery	Air Quality Baseline Monitoring - 3-month averages (Dec 2018-Feb 2019 or Jan-Mar 2019)							LAEI (2013) Modelled Air Quality Concentrations		
	NO_2					VOC	Formaldehyde			
	Roadside - outside	Playground - outside	Nursery Entrance - outside	Nursery Entrance - inside	Classroom - inside			NO_2	PM_{10}	$PM_{2.5}$
Thomas Coram	40.90	26.39	34.86	24.23	23.44	145.90	13.66	44.70	27.40	17.70
Rachel McMillan	36.55	33.11	35.41	21.36	25.55	94.60	4.04	44.10	26.70	16.80
Pembury Housel	63.77	37.67	40.66	21.57	22.50	124.10	8.75	44.20	25.90	16.10
Nell Gwynn	47.20	32.62	35.05	24.40	26.52	190.23	13.64	44.60	26.60	16.70
Columbia Market	44.14	30.52	41.71	32.59	29.00	433.00	3.69	46.80	27.40	17.30
Dorothy Gardner	37.52	34.83	33.21	20.99	24.48	89.80	6.04	41.90	26.30	16.60

3.1.30. There are clear differences between the LAEI modelled NO_2 data and the baseline monitoring data above, though all are high, and mostly exceed the air quality objective of 40 $\mu g/m^3$. These differenced can be attributed to the fact that the LAEI modelled data is based upon historic traffic data and accounts for the whole year, unlike the baseline monitoring which was undertaken for a 3-month period only between December 2018 to February 2019.

3.2 NURSERY ENVIRONMENTS

3.2.1. The environment and conditions for each of the nurseries participating in the trial were recorded in detail at the commencement of the trial, and are summarised below. An expanded write-up for each nursery is provided in Appendix A:

Columbia Market

3.2.2. The nursery site is part of the former Columbia Market and the building is grade 2 listed. The nursery has approximately 80 pupils and 20 staff.

3.2.3. There are three large class rooms for children that surround the courtyard area, and open on to the large playground. The classrooms have high vaulted ceilings and single glazed windows. The nursery is reliant on natural ventilation through opening doors and windows.

3.2.4. The children typically free-flow between the classroom and the playground throughout the day. The doors to the grounds do not have free-flow 'butchers' curtains to retain heat. The playground is exposed to vehicle emission from Pelter Street.

3.2.5. Summary of AFS and control rooms and trial conditions:

- 2 wall-mounted AFS deployed in the Sunflower classroom - mid-sized classroom with pitched roof (approximately 56.6m^2). Naturally ventilated with open windows. External doors in occasional use. Approximately 6-20 children in the classroom, and 1-3 staff.
- Unit operation settings – continuous operation (24 hours), fan speed 3
- The control room was Bluebell classroom, which is comparable with Sunflower classroom.

3.2.6. The baseline air quality monitoring results for Columbia Market were as follows:

- NO2 concentrations were found to be highest at the roadside (44.1µg/m^3), with local road traffic emissions contributing significantly to roadside concentrations. In each month, the measured NO2 concentrations exceeded the annual mean NO2 national Air Quality Objective (AQO) of 40µg/m^3.
- NO2 concentrations fall to 30.52µg/m^3 in the playground, which is partially screened from traffic by fencing and some trees and shrubs. Concentrations at the nursery entrance are higher (43µg/m^3) than the playground.
- Inside the nursery, concentrations both sit above and below external concentrations. During the second month, indoor levels rose above playground concentrations by between 7-9 µg/m^3.
- The NO2 I/O ratio was 0.79 at Columbia Market Nursery School, indicating that uncontrolled infiltration rates are at the higher range of the spectrum, and that the building offers only a limited level of protection to its occupants than a more airtight building.

Rachel McMillan

3.2.7. Rachel McMillan Nursery had 105 full-time equivalent children, with the numbers increasing to about 160 children in the summer term.

3.2.8. The nursery entrance is located on McMillan Street, just south of the staggered junction of McMillan Street / Stowage / Deptford Green. The entrance leads to an outdoor area from which the classrooms (shelters) open onto and are accessed.

3.2.9. The school is heritage listed being constructed in the early 1900's, with the classrooms split over a number of buildings. The classrooms are known as shelters.

3.2.10. The shelters are reliant on natural ventilation by opening windows and doors which back onto the playground. The playground forms an outdoor classroom environment, with children able to flow freely between the playground and shelters.

3.2.11. The classrooms large windows and doors, and given the age of the building are likely to be poorly insulated, which would result in greater heat loss, and so potentially increased run times by school boilers, and therefore greater emissions. It also results in higher temperatures during warmer weather, requiring windows/doors to be opened and so greater exposure. The school noted that heating is not even between shelters.

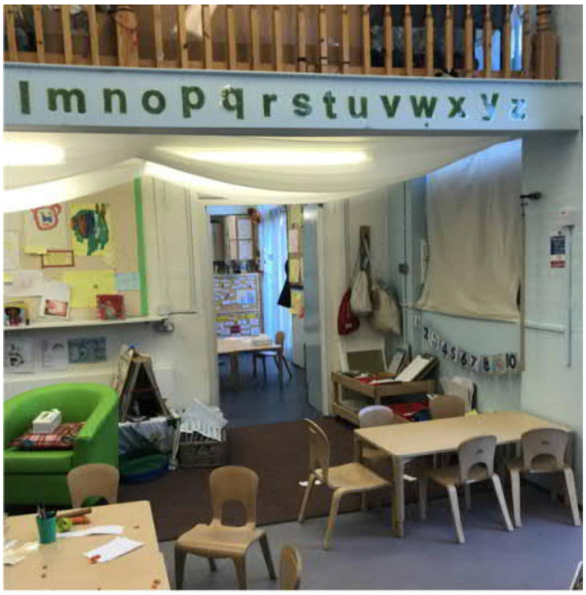
3.2.12. Summary of AFS and control rooms and trial conditions:

- 2 floor-standing AFS deployed in the Shelter 4 classroom - mid-sized classroom (approximately 88 m^2). Naturally ventilated with open windows. External doors in regular use. Approximately 15 children in the classroom, and 2-3 staff.
- Unit operation settings – continuous operation (24 hours), fan speed setting 2
- The control room was Shelter 3 classroom, which is comparable with Shelter 4 classroom.

3.2.13. The baseline air quality monitoring results for Rachel McMillan were as follows:

- NO2 concentrations were found to be highest at the roadside (36.55µg/m^3), with local road traffic emissions contributing significantly to roadside concentrations.
- NO2 concentrations fall to 33.11µg/m^3 in the playground, which is partially screened from traffic by fencing and some trees and shrubs. Concentrations at the nursery entrance are of a slightly higher level (35.41µg/m^3) to the playground.
- Inside the nursery, concentrations fall by 7-18µg/m3 compared to external concentrations.
- The NO2 I/O ratio was 0.60 at Rachel McMillan Nursery School, indicating that uncontrolled infiltration rates are at the lower end of the spectrum, and so offers a reasonable level of protection to its occupants relative a more airtight building.

Nell Gwynn



3.2.14. At the time of the audit the nursery had 169 children, of which 21 are full time (30 hrs per week), and the remainder (158) are part time (15hrs per week).

3.2.15. The nursery is housed in a brick built building constructed in 1911, and was formerly a school, and prior to that the site was a brewery. The majority of the building is single storey with high pitched roofs, though there are mezzanine floors in a corner of each classroom, and within the main hall.

3.2.16. The classrooms open out onto the 2-year old's playground, and the children typically free-flow between the classroom and the playground throughout the day. The external doors are left open, with a butchers curtain fitted to retain the heat.

3.2.17. The four 3-4-year-old classrooms are located at the rear of the nursery, away from Meeting House Lane and the construction site. The classrooms each have large windows and double height ceilings, with external doors leading to the rear playground. The children typically free-flow between the classroom and the playground throughout the day. The playground backs onto residential properties, and to the police station on the southern boundary, with is some limited vegetation.

3.2.18. Summary of AFS and control rooms and trial conditions:

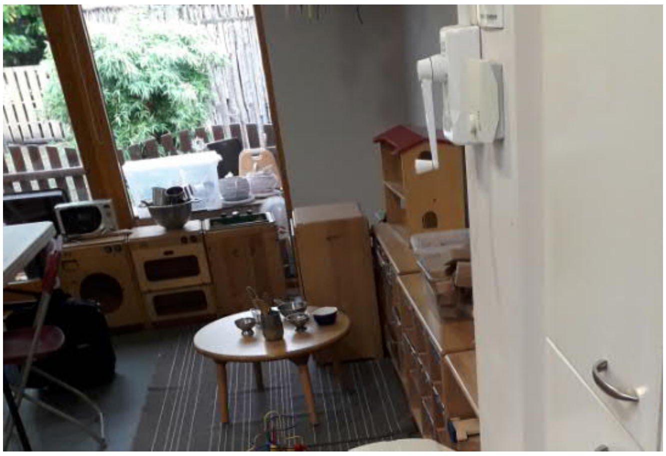
- 2 wall-mounted AFS deployed in the 3-4-year-old classrooms are located at the rear of the nursery. Mid-sized classroom with double-height ceilings and mezzanine area (approximately 70 m^2). Naturally ventilated with open windows. External doors in regular use. Approximately 12-15 children in the classroom, and 2-3 staff.
- Unit operation settings – continuous operation (24 hours).
- The control room was a second comparable 3-4 year olds classroom.

3.2.19. The baseline air quality monitoring results for Nell Gwynn were as follows:

- NO2 concentrations were found to be highest at the roadside (47.20µg/m^3), with local road traffic emissions contributing significantly to roadside concentrations. In each month, the measured NO2 concentrations exceeded the annual mean NO2 national Air Quality Objective (AQO) of 40µg/m^3.
- NO2 concentrations fall to 32.62µg/m^3 in the playground, which is partially screened from traffic by fencing and some trees and shrubs. Concentrations at the nursery entrance, which is not screened from the road, are slightly higher than in the playground (35.05µg/m^3).
- Inside the nursery, concentrations fall to 24.40µg/m3 at the nursery entrance and 26.52µg/m3 in the classroom.
- The NO2 I/O ratio was 0.70 at Nell Gwynn Nursery School, indicating that uncontrolled infiltration rates are at the higher end of the spectrum, and so offer less protection to its occupants than a more airtight building.

Pembury House

3.2.20. At the time of the audit the nursery had 175 children.



3.2.21. The nursery is a single storey building, built in the 1970s, and extensively refurbished in the 1990s.

3.2.22. The majority of the building is screened from Lansdowne Road by the tyre business building with the entrance of the nursery protruding to the street at the eastern end.

3.2.23. The nursery is reliant on natural ventilation through opening doors and windows. The classrooms feature high ceilings and large windows. The main class room is positioned at the southern end of the site, away from the entrance and Lansdowne Road, and faces a playground garden. The main classroom has a vaulted ceiling that falls from the centre of the building at a height of approximately three metres to the southern wall and playground garden. Two external doors are left open and PVC free flow curtains (butchers curtains) are used to retain heat. The nursey has also a few enclosed class rooms used in the morning and occasional events.

3.2.24. Children free-flow between the classroom and playground garden to the rear of the site. The playground wraps around to the western side where there is a gap in the buildings to Rheola Close.

3.2.25. Summary of AFS and control rooms and trial conditions:

- 1 floor-standing AFS deployed in the Creche/ Family Room - a small room (approximately 40 m^2). Naturally ventilated with open windows and a door. The room was used by parent /toddler and clinic groups with varying numbers of children and staff. It is also used for childrens events in the evenings.
- Unit operation settings – continuous operation (24 hours)
- The control room was a classroom, which is comparable with the Family Room.

3.2.26. The baseline air quality monitoring results for Pembury House were as follows:

- NO2 concentrations were found to be highest at the roadside (63.774µg/m^3), with local road traffic emissions contributing significantly to roadside concentrations. In each month, the measured NO2 concentrations exceeded the annual mean NO2 national Air Quality Objective (AQO) of 40µg/m^3.
- NO2 concentrations fall to 37.67µg/m^3 in the playground, which is partially screened from traffic by fencing and some trees and shrubs. Concentrations at the nursery entrance are of a higher level (40.66µg/m^3) to the playground.
- Inside the nursery, concentrations fall by 15-42µg/m3 compared to external concentrations.
- The NO2 I/O ratio was 0.53 at Pembury House Nursery School, indicating that uncontrolled infiltration rates are at the lower end of the spectrum, and so offer reasonable protection to its occupants.

Thomas Coram

3.2.27. At the time of the audit the nursery had 125 children. It also caters for 32 full-time equivalent toddlers, provided as two groups of about 39 children. The nursery has over 30 members of staff.

3.2.28. The nursery is housed in a modern brick built building which is 21 years' old. The nursery is essentially split into two wings which are classroom areas, connected by the administration, office and staff area in the middle.

3.2.29. Each wing has direct external access to a playground. The children typically free-flow between the classroom and the playground throughout the day, with exception of lunch break and an initial settling in period. Some, but not all the external doors are left open, with a butcher's curtain fitted to retain the heat.

3.2.30. The playground is fenced with high metal mesh fencing, which has a green covering to increase screening from adjacent uses.

3.2.31. The classrooms feature relatively low ceilings and large windows. The nursery is mostly reliant on natural ventilation through opening doors and windows.

3.2.32. Summary of AFS and control rooms and trial conditions:

- 1 floor-standing AFS deployed in the Yellow classroom - mid-sized classroom (approximately 48 m^2) with low-ceilings. Naturally ventilated with open windows. External doors in regular use via an adjoining conservatory/corridor leading to the playground. Approximately 16 children in the classroom, and 4 staff.
- Unit operation settings – automatic setting, turning off and on as needed. Continuous operation (24 hours).
- The control room was Shelter 3 classroom, which is comparable with Shelter 4 classroom.
- The control room was Green classroom, which is comparable with Yellow classroom on a separate wing of the building.

3.2.33. The baseline air quality monitoring results for Thomas Coram were as follows:

- NO2 concentrations were found to be highest at the roadside (40.90µg/m^3), with local road traffic emissions contributing significantly to roadside concentrations.
- NO2 concentrations fall to 26.39µg/m^3 in the playground, which is partially screened from traffic by fencing and some trees and shrubs. Concentrations at the nursery entrance were a higher concentration (34.86µg/m^3) to the playground.
- Inside the nursery, concentrations fall by 11-11g/m3 compared to external concentrations.
- The NO2 I/O ratio was 0.70 at Thomas Coram Centre, indicating that uncontrolled infiltration rates are at the higher end of the spectrum, and so the building offers less protection to its occupants than a more airtight building.

Dorothy Gardner

3.2.34. At the time of the audit the nursery could accommodate up to 87 children.

3.2.35. The main entrance to the nursery is via Shirland Road. The nursery has one playground, that is located directly adjacent to the roundabout with Shirland Road and Fernhead Road. There is limited screening from the surrounding roads, in the form of a fence and some greenery.

3.2.36. The building itself is thought to be of 1970s construction and is split over two storeys, and is reliant on natural ventilation.

3.2.37. The main classroom used by children is located closest to the Fernhead Road and Shirland Road roundabout, which has large windows and high ceilings, with external doors leading to the playground. Children are able to free-flow between the classroom and the playground throughout the day. The room is reliant on natural ventilation and it was noted from staff that the nursery often have the doors to the playground left open for access to the playground, even in the colder months, which results in greater heat loss and so potentially results in increased run times by nursery boilers and therefore emissions. The nursery has also a few enclosed small class rooms often used by small children.

3.2.38. The boiler is located in a single plant room and was considered by the nursery caretaker to be in ‘good’ condition. It is 14 years and the flues exit onto the roof, away from areas used by children. The boiler would need to be maintained to extend its life span as it already has more than 10 years of service.

3.2.39. Summary of AFS and control rooms and trial conditions:

- 1 wall- mounted AFS deployed in a down-stairs small-sized classroom (approximately 25 m^2) with low-ceilings. Naturally ventilated with open windows. Approximately 10 children in the classroom, and 3 staff.
- Unit operation settings – automatic setting, turning off and on as needed. Continuous operation (24 hours).
- The control room was a second comparable classroom.

3.2.40. The baseline air quality monitoring results for Thomas Coram were as follows:

- NO2 concentrations were found to be highest at the roadside (37.52$\mu g/m^3$), with local road traffic emissions contributing significantly to roadside concentrations. In each month, the measured NO2 concentrations slightly exceeded the annual mean NO2 national Air Quality Objective (AQO) of 40$\mu g/m^3$.
- NO2 concentrations were found to be slightly lower (34.83 $\mu g/m^3$) in the playground, which is partially screened from traffic by fencing and some trees and shrubs. Concentrations at the nursery entrance are of a lower level (32.21 $\mu g/m^3$) to the playground.
- Inside the nursery, concentrations fall by 9-17 $\mu g/m^3$ compared to external concentrations.
- The NO2 I/O ratio was 0.64 at Dorothy Gardner Nursery School, indicating that uncontrolled infiltration rates are at the intermediate end of the spectrum, with the building offering a moderate level of protection to its occupants.

4

AIR FILTRATION SYSTEMS TRIAL METHODOLOGY

4 AIR FILTRATION SYSTEMS TRIAL METHODOLOGY

4.1 DETERMINING INDOOR AIR QUALITY DURING AIR FILTRATION SYSTEMS TRIAL

4.1.1. The purpose of the Air Filtration Systems (AFS) trial was to establish their performance in "real world" nursery environments, i.e., in classrooms or spaces where young children spend a significant amount of time and may be exposed to poor air quality, as part of the Mayor's Nursey Air Quality Audit Programme.

4.1.2. An independent web-based "randomiser" was used to assign each of the six shortlisted AFS amongst the six nurseries selected for the trial.

4.1.3. The table below provides details of the air pollutants removed by the AFS assigned to each nursery, and the dates during which the period of continuous monitoring was undertaken at each.

4.1.4. The intention of this trial has been to determine the general effectiveness of the AFS technologies in these unique settings, rather than directly compare the performance of the selected AFS units with one another, as it was recognised each was operating in very particular conditions. Consequently, the supplier's details are anonymised when reporting on each specific site, with assessments focusing on establishing the effectiveness of each AFS in its given environment.

Table 4-1 –AFS Installed in Each Nursery and Continuous Monitoring Period

Air Filtration System	Nursery School	Local Authority	Air Pollutants removed by the AFS	Continuous Monitoring	
				Start Date	End Date
1	Nell Gwynn	Southwark	$PM_{2.5}$, PM_{10}	18/04/2019	02/05/2019
2	Columbia Market	Tower Hamlets	NO_2, $PM_{2.5}$, PM_{10}	04/05/2019	16/05/2019
3	Rachel McMillan	Greenwich	$PM_{2.5}$, PM_{10}	17/05/2019	06/06/2019
4	Pembury House	Haringey	$PM_{2.5}$, PM_{10}	07/06/2019	20/06/2019
5	Thomas Coram	Camden	$PM_{2.5}$, PM_{10}	21/06/2019	04/07/2019
6	Dorothy Gardner	Westminster	$PM_{2.5}$, PM_{10}	26/07/2019	08/08/2019

4.1.5. The AFS were installed in one classroom at each location for a period of six months. The rooms in which the AFS were installed were decided by site visits prior to installation.

4.1.6. The site visits considered infrastructure constraints, e.g., volume of the room, access to mains electricity, ease of installation, and so on, as well as the on-going use of the room and hence its suitability for use in the trials. 'Control' classrooms were typically an adjacent classroom of similar dimensions (volume), though it was not possible to use an adjacent room in each case.

4.1.7. The sampling methodology used to determine the effectiveness of the AFS to reduce nursery children's exposure to poor air quality during the trial is outlined below.

4.2 SAMPLING METHODOLOGY

4.2.1. As part of the Mayor's Nursey Air Quality Audit Programme, a baseline NO_2 survey was undertaken at twenty nursery schools throughout London followed by a more intense phase of measurements which were conducted at the six nurseries selected as part of the AFS trial. These provided external and internal air quality measurements at each nursery (see Section 3.1.13).

INTENSIVE AIR QUALITY MONITORING

4.2.2. The approach taken in monitoring air the effect of AFS upon indoor air quality within the AFS classroom was an outcome of the following criteria:

- Monitoring equipment was required to be discrete, small and have a low impact
- Requirement for monitoring method to be low-noise
- Monitoring was required to provide reliable robust concentration data
- Monitoring was required to provide a detailed understanding of changes in indoor air quality within nursery classrooms as a result of installing the AFS

4.2.3. A combination of passive (diffusion tubes) and active (Zephyr) monitoring techniques were used to determine internal air quality concentrations and trends during the AFS trial. Ozone monitoring was undertaken using two reference method ultraviolet photometry O_3 monitors.

4.2.4. The monitoring devices sampled the classroom with the AFS and a separate "control classroom" elsewhere within the nursery, with similar characteristics but no AFS installed. The effectiveness of the AFS system is represented by the difference between the AFS and control classrooms.

4.2.5. Use of two separate methods for NO_2 monitoring was to exploit each sampling method for a distinctly different function. Nitrogen dioxide diffusion tubes are a reliable monitoring method, providing a record of absolute NO_2 concentrations in the classrooms, though are only capable of one concentration record per month. Nitrogen dioxide Zephyr results are known to contain an element of uncertainty and so should not be overly relied upon for absolute concentration data. However, the instrument is capable of providing an impressive near instantaneous response to changes in NO_2 concentrations, allowing a detailed trace of changes in NO_2 concentrations to be obtained for the entire 2-week sampling for each classroom, with this instantaneous response comes a degree of uncertainty.

Selection of monitoring methodology

4.2.6. A combination of passive (diffusion tubes) and active (continuous) monitoring techniques allowed the effectiveness of the AFS reduce nursery children's exposure to poor air quality over the working day to be determined.

4.2.7. Nitrogen dioxide diffusion tubes provide reliable low-cost concentration data, with one sample taken per month. Therefore, long-term changes in indoor NO_2 can be assessed between the nursery classroom with an AFS installed and a neighbouring classroom with no AFS, which was used as a control nursery classroom.

4.2.8. Indicative Zephyr air quality monitoring devices provided determination of short-term temporal changes in air quality. Indicative air quality monitoring devices provide a high-resolution air quality data which can be interpreted as qualitative. It is known that absolute gas concentration magnitudes between two co-located identical indicative air quality monitoring devices can vary, though trends and responses to changes in concentrations remain the same. Therefore, in this study the absolute NO_2 concentration data was taken from the diffusion tube data with significant reference made to results from indicative air quality monitoring data for NO_2.

4.2.9. The order in which the continuous measurements were conducted at the six nurseries was decided at random prior to the start of the trial; however, passive measurements were conducted throughout all of nurseries for the whole six month duration of the AFS trial.

Diffusion Tube Monitoring

4.2.10. Nitrogen dioxide diffusion tubes were deployed between April and October 2019 in the AFS and control classrooms at the six nurseries. The raw (non-bias adjusted) results are given in Appendix G.

4.2.11. Whilst diffusion tubes provide a robust measure of NO_2 concentrations over a month, to determine the effectiveness of the AFS to reduce nursery children's exposure to poor air quality over the working day, higher time resolution, continuous analysers were used to determine temporal trends. These instruments are described next.

Zephyr Sensor Monitoring

4.2.12. Earthsense Zephyrs are small, indicative air quality monitoring devices which use electrochemical sensors to measure NO_2 (and O_3) and optical particle counters to measure $PM_{2.5}$ concentrations in ambient air. They also have integrated barometric pressure, relative humidity and temperature sensors providing an extensive range of air quality and meteorological data.

4.2.13. Zephyr sensors are mains powered but also have an internal battery which can provide system power for a limited time. This allows measurements to continue uninterrupted should the device be accidentally disconnected from the mains by a child or teacher – this was identified as a potential risk during the monitoring phase design, which could have led to the loss of data.

4.2.14. The design of the Zephyr sensor is optimised to ensure they are quiet therefore their operation was imperceptible during the working nursery day and would not potentially distract the children or disrupt classes, thereby limiting the potential interference with the normal nursery routine.

4.2.15. Two Zephyr sensors were deployed at each nursery, one in the classroom where the AFS was installed, the second in the control classroom. Continuous measurements of NO_2 and $PM_{2.5}$ were made over a fortnight (Friday-Thursday) at each nursery to provide a 'snapshot' of the air filtration system's performance providing over 300 hours of data at each nursery.

4.2.16. Zephyr data was logged directly to a cloud-based server in near-real time every minute. Data was screened daily via the Earthsense website during the working week and downloaded at the end of each fortnight measurement period.

4.2.17. The same continuous air quality sensors were used throughout the trials, with the same device being installed in the AFS or control room each time.

Ozone Monitoring

4.2.18. Ozone gas monitoring was undertaken at several nurseries where the AFS was known to use O_3 internally as part of the 'air cleaning process', to verify the effectiveness of the units in mitigating the ozone generation as reported in test results and independent accreditations supplied.

4.2.19. High O_3 concentrations can represent are a health hazard leading to the irritation of airways, causing breathing difficulties and lung damage. The effects are more noticeable in people with asthma and other lung problems. Indoor O_3 levels are generally lower than outdoor concentrations and are driven by natural ventilation with external ambient air entering via gaps and cracks in walls, as well as through the opening of windows and doors. Photocopiers, printers and soft furnishings can also emit ozone and influence indoor concentrations.

4.2.20. To help determine whether the AFS installed in four of the nursery schools were fully effective in managing and abating O_3 generated as part of the 'air cleaning process', two reference method (BS EN 14625) ultraviolet photometry O_3 monitors were deployed for a fortnight at four of the six nurseries: Nell Gwynn, Columbia Market, Rachel McMillan and Pembury House.

4.2.21. The O_3 monitor, were installed in the same locations as the Zephyr sensors in the AFS and control classrooms, though this was not feasible in all cases due to physical constraints (the size difference between a Zephyr sensor and an O_3 monitor). Sampling O_3 concentrations simultaneously within an AFS and control nursery classroom would allow systematic differences in O_3 concentrations between the two environments to be identified.

4.2.22. Ozone concentrations were recorded every minute by the monitors and downloaded manually on a weekly basis.

4.3 DATA ANALYSIS

4.3.1. Hourly NO_2 and $PM_{2.5}$ mean concentrations were calculated from the Zephyr data and 15-minute mean O_3 concentrations were calculated from the O_3 monitoring data.

4.3.2. The effectiveness of the AFS system to reduce nursery children's exposure to poor air quality over the working day at each nursery is represented by the difference in NO_2, both in terms of the Zephyr sensor and diffusion tube monitoring data, and $PM_{2.5}$ concentrations between the AFS and control classrooms.

4.3.3. The effectiveness of the AFS system was also determined by examining the O_3 measurements to ensure they were not at higher concentrations in the AFS classroom than the control classroom.

4.4 STUDY LIMITATIONS

4.4.1. The study limitations are summarised below.

Diffusion Tube Monitoring

4.4.2. Nitrogen dioxide diffusion tubes were deployed between April and October 2019 in the AFS and control classrooms at the six nurseries which took part in the AFS trials. Due to resource constraints, not all nurseries were able to return all tubes deployed for analysis.

4.4.3. Due to delays in installing the AFS at Pembury House and Dorothy Gardner, only five months of diffusion tube monitoring took place at these two nurseries, with Dorothy Gardner returning three months of exposed diffusion tubes.

Zephyr Sensor Monitoring

4.4.4. 87 hours of Zephyr data was lost between 01:00hrs on the 19/05/2019 and 16:00hrs on 22/05/2019 during the measurements at Rachel McMillan. This was caused by a power supply fault. To compensate for this, an additional week of measurements were obtained.

Ozone Monitoring

4.4.5. Data coverage for the reference O_3 monitoring was at least 93% in most cases meaning 311 out of a total of 336 hours of O_3 measurements were collected. Data coverage for Nell Gwynn was lower at 74%.

TSI SidePak Personal Aerosol Monitor

4.4.6. It had initially been intended to TSI SidePak Personal Aerosol Monitor (model AM510) to measure of PM2.5 concentrations. These are lightweight, rugged, compact and quiet optical particle counters making them ideal for this study. Due to a fault with the instruments which was detected during regular instrument testing, the study measurements were discounted.

4.5 AFS INSTALLATION AND SET-UP

4.5.1. A formal invitation letter was sent to the six shortlisted AFS suppliers, and outlining the trial methodology.

4.5.2. All the suppliers had the opportunity to undertake a site visit of their allocated nursery prior to the commencement of the trial, to review the site their AFS is to be located within, and propose the most suitable unit for the site, subject to agreement from the nursery.

4.5.3. The AFS suppliers installed and set-up their units upon the commencement of the trial, to ensure the installation was in line with the manufacturer's guidelines. The suppliers were accompanied by a member of the consultant team to observe the set-up process.

4.5.4. Whilst the supplier was free to specify the equipment and set-up to most effectively clean this space, this had to be agreed with the nursery, with due consideration given to the practical use of the space staff and children. A key feature of the trial was to ensure that unrealistic demands were not placed upon the nursery in terms of their usual operations. For example, they were expected to maintain free-flow for children between classrooms and outdoor spaces, and the opening of windows and doors to ventilate the room. Suppliers had the opportunity to advise nursery staff on how to best utilise the AFS, but the intention has not been to artificially create the optimum operating conditions.

4.5.5. The selected nurseries and AFS suppliers signed consent forms. The suppliers were also required to produce and share a Risk Assessment and Method Statement (RAMS) in order to guarantee health and safety throughout the installation trial phases.

4.5.6. The suppliers were required to deliver a safety and operating briefing to nursey staff, or to provide the necessary information and materials for the consultant team to deliver a briefing. Suppliers also briefed the nurseries on the operating procedures, and any risks associated with the AFS (and respective filters) dismounting and disposal.

4.6 AFS CHECKS AND INSPECTIONS

4.6.1. The consultant team undertook periodic safety checks throughout the trial, and the suppliers were required to provide an emergency call out number in case of any problems.

4.6.2. There were no emergency call outs during the trial, only a few instances where units were accidently turned off (cleaners having unplugged them for example), so telephone support was required to restart the AFS on the same settings for the purposes of the trial.

4.6.3. During the trial the consultant team managing the trial also undertook visits to check system functionality and undertake visual inspections.

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AIR FILTRATION SYSTEM TRIAL RESULTS

5 AIR FILTRATION SYSTEM TRIAL RESULTS

5.1 OVERVIEW OF AFS MONITORING RESULTS

5.1.1. An overview of the diffusion tube and continuous monitoring data is contained in **Table 5-1** below, where is can be seen that diffusion tube data indicated a positive reduction of NO_2 concentrations in 3 of the 6 nurseries when comparing the AFS classroom to the control classrooms. With diffusion tube results from Columbia Market, Nell Gwynn and Dorothy Gardner indicating that NO_2 concentrations were slightly higher in the AFS classroom than the control classroom. On average, the NO_2 concentrations from the diffusion tubes in the AFS classrooms were lower than the control classrooms by between 1 to 4µg/m^3. Generally, continuous sampling data generated from using the indicative Zephyr monitors confirmed that peak NO_2 concentrations were reduced in AFS classrooms in comparison to the control classrooms.

5.1.2. Zephyr data for $PM_{2.5}$ indicated concentrations were lower in AFS classrooms than control classrooms, with fewer peaks occurring in $PM_{2.5}$ concentrations in AFS classrooms than control classroom. For the monitoring period, all AFS were seen to be successful in reducing $PM_{2.5}$ concentrations in AFS classrooms.

Table 5-1 - Summary of the AFS Monitoring Survey Pollutant Reduction Detected *(Red negative reduction; White negligible; Green – positive reduction)*

Nursery	Effective NO_2 Reduction		Effective $PM_{2.5}$ Reduction	Effective Ozone Reduction
	Diffusion Tube	Zephyr		
Nell Gwynn	Negligible detected	Reduced peak hour NO_2 concentration in AFS classroom	Positive $PM_{2.5}$ reduction by approximately 0.8µg/m^3	Slight increase in O_3 detected
Columbia Market	Negligible detected	Reduced peak hour NO_2 concentration in AFS classroom	Positive $PM_{2.5}$ reduction by between 5 to 6µg/m^3.	Negligible difference detected
Rachel McMillan	N/A	Some minor reduction in AFS peak hour NO_2 in the afternoon, though minor increase in morning	Positive $PM_{2.5}$ reduction by approximately 0.3µg/m^3.	Negligible difference detected
Pembury House	Significant positive reduction with difference detected of 5.8µg/m^3	Significant NO_2 reduction in AFS throughout the day	Positive $PM_{2.5}$ reduction by up to 3µg/m^3	Positive O_3 reduction by between 4 to 6µg/m^3.

Nursery	Effective NO_2 Reduction		Effective $PM_{2.5}$ Reduction	Effective Ozone Reduction
	Diffusion Tube	Zephyr		
Thomas Coram	Successful positive reduction of 2.2µg/m^3 detected	Reduced peak hour NO_2 concentration in AFS classroom	Positive $PM_{2.5}$ reduction by between 0.2 to 1µg/m^3.	N/A
Dorothy Gardner	N/A	Reduction in NO_2 concentrations in AFS classroom	Positive $PM_{2.5}$ reduction by approximate 1 µg/m^3	N/A

5.1.3. Zephyr data and Ozone analyser data indicated that peaks in NO_2, $PM_{2.5}$ and O_3 occurred during midweek periods in the classrooms, though were absent at the weekend. This corresponds to increased activity at the nurseries during midweek periods, with nurseries largely unoccupied at the weekends, with fewer opportunities for ingress of external polluted air into the classrooms.

5.1.4. Therefore, it was concluded from observations of sampling results that a significant source of NO_2 and O_3 was intrusion of external ambient air into the nursery classrooms. This occurred during midweek day-time periods, and was generally absent over the weekend. Limiting the intrusion of polluted air through closing doors and windows, as well as improving air tightness of nursery classroom, would therefore reduce both NO_2 and O_3 concentrations in the classrooms.

5.2 SUMMARY OF THE MONITORING UNDERTAKEN

5.2.1. Monitoring of the AFS performances using $PM_{2.5}$, NO_2 and O_3 monitoring methods. All AFS were designed to reduce $PM_{2.5}$ concentrations, five of the six all claimed to be capable of reducing NO_2 concentrations, therefore, the universal parameter of whether AFS are capable of improving indoor air quality is their ability to reduce whether $PM_{2.5}$ concentration.

5.2.2. Monitoring data collected at the six nurseries during AFS trial is presented below together with an interpretation of the findings.

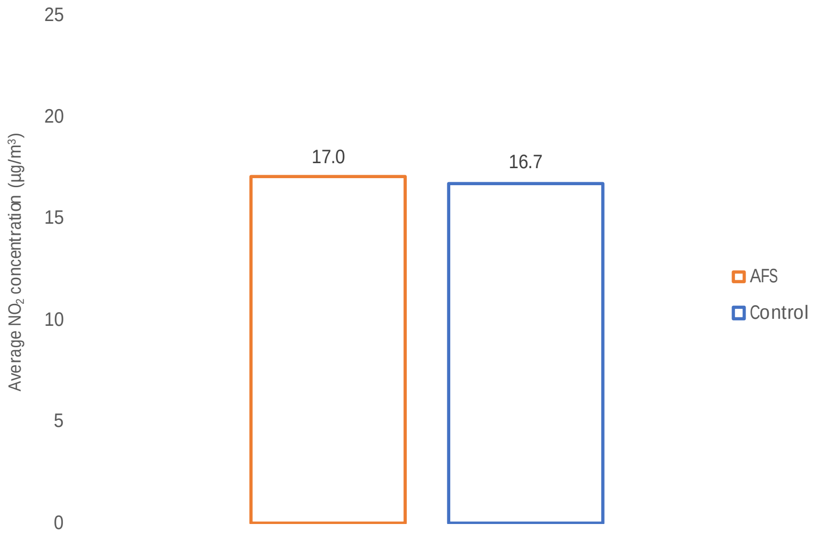
5.2.3. Nitrogen dioxide diffusion tubes were deployed at each of the 6 nurseries for a total period of 6 months. The Zephyrs were deployed at each nursery for a period of between 11 to 14 days, therefore they represent a shorter sampling period than diffusion tubes. In addition, the Zephyr instruments are an indicative sampling method, used to determine short-term changes and trends. The diffusion tube data are considered to be more representative of NO_2 concentrations within the Nursery classrooms, as they were collected over a three-month period, are attributed to a ISO 17025 traceable methodology (BS EN 13528). Though diffusion tubes are still an indicative method, with an uncertainty of ± 25%[10], they are accepted as a valid sampling method and have a significantly greater repeatability than the Zephyrs NO_2 monitoring.

5.3 NELL GWYNN NURSERY SCHOOL

DIFFUSION TUBE MONITORING RESULTS

5.3.1. The average NO_2 concentration in the AFS and control classroom from the six-month diffusion tube measurements at Nell Gwynn show that concentrations in the AFS and control room are broadly similar at 17µg/m^3.

Figure 5-1 - Nell Gwynn Diffusion Tube Monitoring Results at Nell Gwynn Nursery - Average NO_2 (µg/m^3)



ZEPHYR SENSOR MONITORING RESULTS

NO_2 Measurements

5.3.2. Though the AFS installed at Nell Gwynn does not specifically remove NO_x, NO_2 Zephyr monitoring results, Figure 5-2, indicate differences exist between the AFS and control room NO_2 concentrations, with higher concentrations in the control room for the majority for the time. Peak NO_2 concentrations were limited during the weekend (20th to 21 April, and 27th to 28th April). The AFS classroom generally experienced lower NO_2 peak values than the control classroom.

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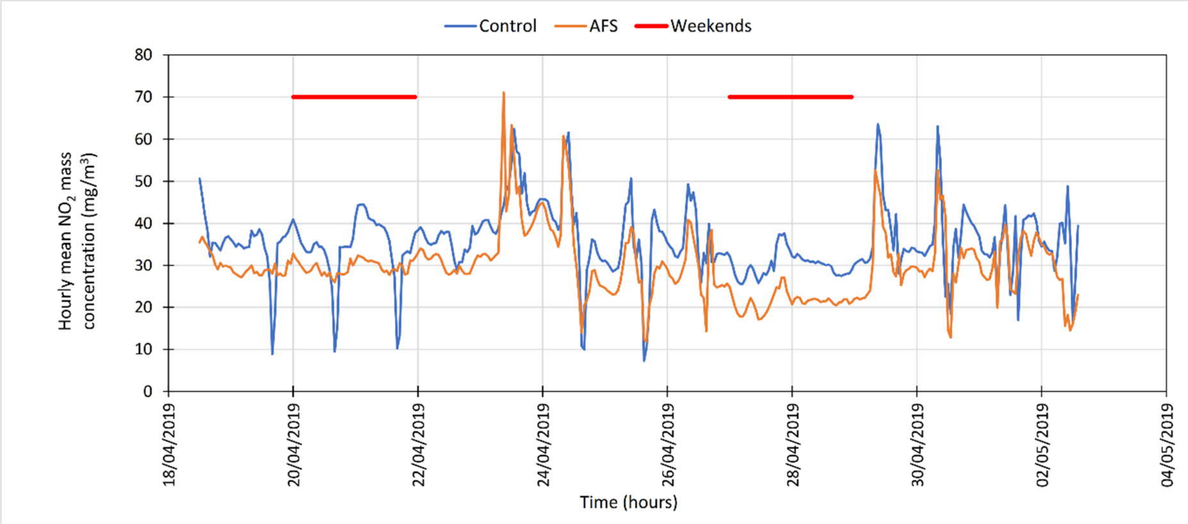
[10] Diffusion Tubes for Ambient NO_2 Monitoring: Practical Guidance AEA/ENV/R/2504 (2008), AEA Energy & Environment

Figure 5-2 - Nell Gwynn Zephyr Sensor Monitoring Results NO_2 Concentration (µg/m^3)

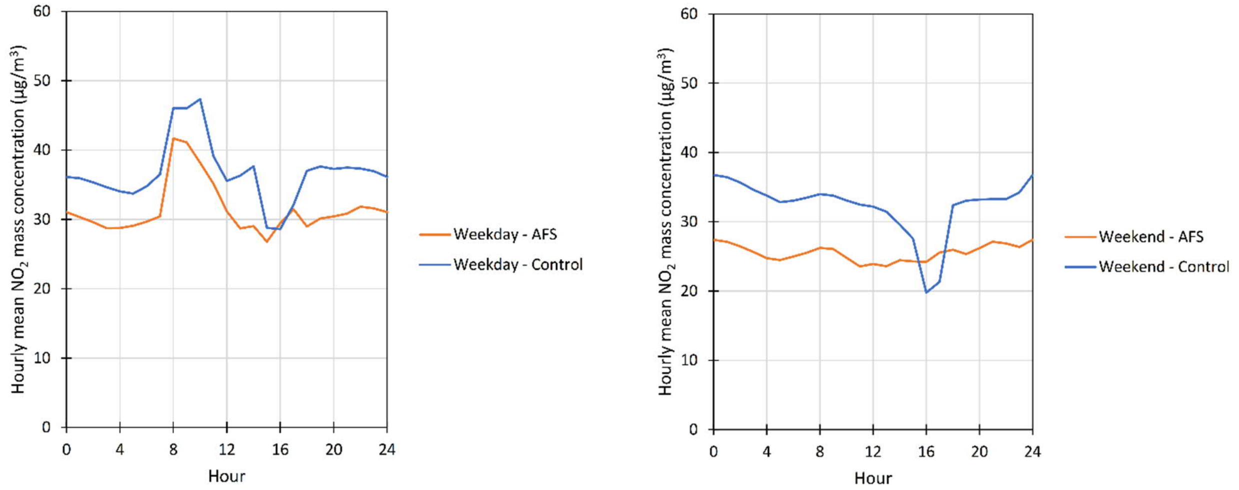


5.3.3. Hourly average data (Figure 5-3) indicate that in the control room, concentrations tended to rise above 40µg/m^3 between 08:00hrs and 11:00hrs, whilst concentrations in the AFS room exceed 40µg/m^3 at the same time but for a less sustained period.

5.3.4. These rises in NO_2 concentrations during the morning period are likely to be associated with localised intrusion of street sourced air, through open doors and windows for both the AFS and Control room. Weekend NO_2 concentrations in both rooms are lower than weekday concentrations. A noticeable dip in control room concentrations occurs at 16:00hrs during the week and at the weekend. This coincides with the end of the Nursery school day, and is likely to be associated with the closing of external doors and windows.

5.3.5. Differences in NO_2 concentrations between the AFS and Control rooms reduced during peak concentrations, indicating that the effectiveness of the AFS to remove NO_2 concentrations is diminished during peak concentrations, however the AFS is was effective at reducing NO_2 concentrations. This may be associated with short-term intrusion of intrusion ambient air into the nursey classrooms, from open doors and windows.

Figure 5-3 - Nell Gwynn Zephyr Sensor Monitoring Hourly Average NO_2 Concentration (µg/m^3)

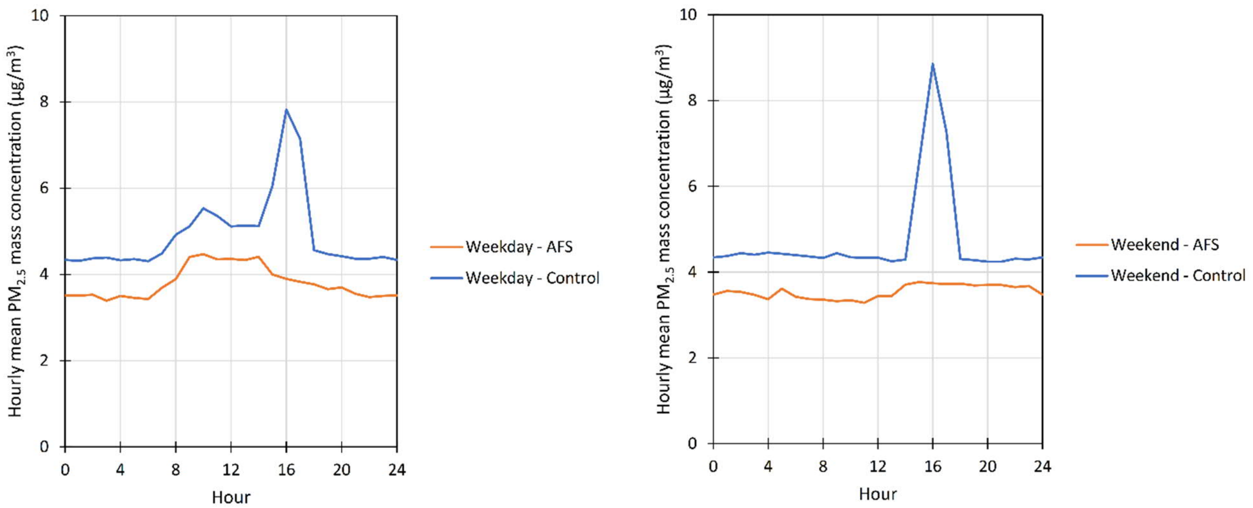


$PM_{2.5}$ Measurements

5.3.6. As with the NO_2 measurements, slightly higher $PM_{2.5}$ concentrations were seen in the control room than the AFS room as shown in Figure 5-4. In both rooms, concentrations were around 5µg/m^3.

5.3.7. A small peak in $PM_{2.5}$ concentrations can be seen in both the weekday AFS and control room measurements around mid-morning. This may be related to the movement of staff and children causing an increase in resuspended dust as this feature is absent at the weekend.

Figure 5-4 - Nell Gwynn Zephyr Sensor Monitoring Hourly Average $PM_{2.5}$ Concentration (µg/m^3)

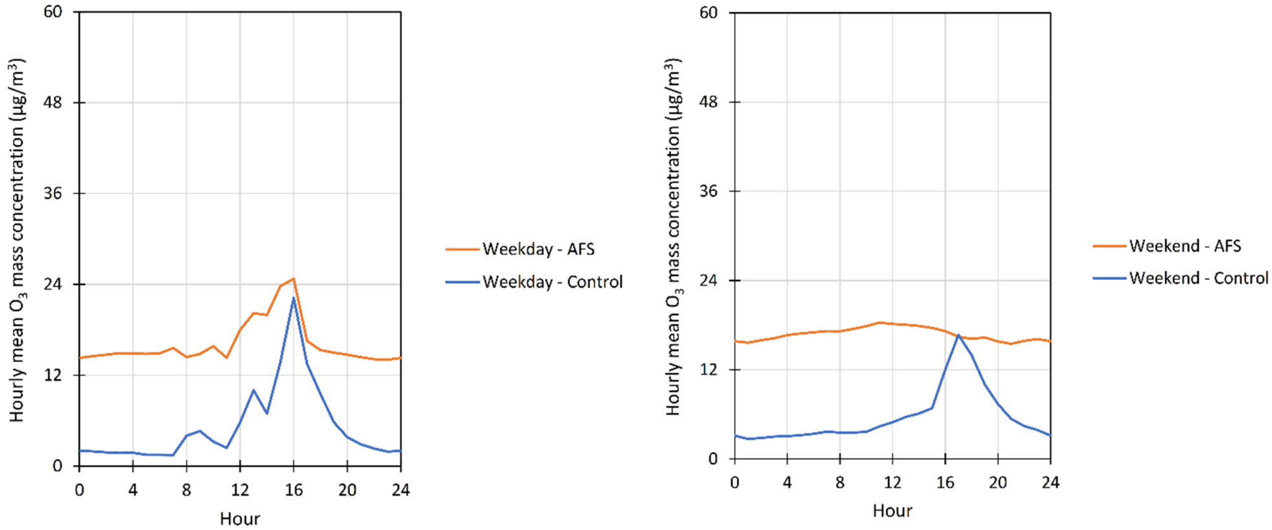


5.3.8. Weekend $PM_{2.5}$ concentrations in both rooms are lower than weekday concentrations. A sharp spike in $PM_{2.5}$ concentrations occurs in both the control room concentrations between 16:00hr and 17:00hrs during at the weekend and midweek, with no corresponding spike in concentration within the AFS classroom. This could be associated with either cleaning activities, or a particulate source associated with the control room.

OZONE MONITORING RESULTS

5.3.9. Figure 5-5 shows the temporal trend in the 15-min O_3 concentrations, measured in the AFS and control classrooms by the reference O_3 monitor.

Figure 5-5 - Nell Gwynn 15-min Average O_3 Concentration (µg/m^3)



5.3.10. Concentrations of O_3 in both the AFs and control classrooms were very low in both nursery classrooms. Concentrations of O_3 were slightly higher in the AFS room, by approx. 3µg/m^3, during both the week and weekend. Peaks in O_3 concentrations generally occurred in late afternoon, between 15:00hr to 17:45hr. Ozone concentrations in both classrooms were well below the air quality objective concentration of 100µg/m^3.

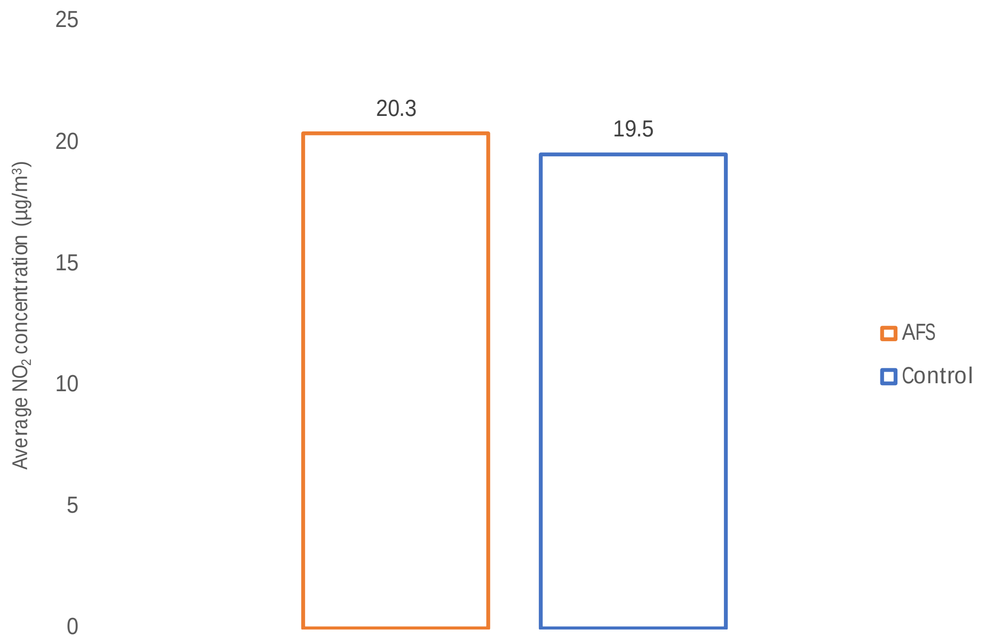
5.3.11. Both week day and weekend concentrations follow similar temporal trends, with an increase in O_3 concentrations after 08:00hrs and peaking at round 16:00hrs before falling throughout the evening. These increases are co-incidental with photochemical production of ambient ozone. Increases in O_3 concentrations also occur within the control room during the weekday period. Weekend O_3 concentrations in both the AFS classroom and control classroom follow a similar pattern with slightly higher concentration within the AFS classroom. Peaks and troughs in O_3 concentrations were present for both the AFS classroom and control classroom during the weekday period. These are likely to be associated with opening and closing of doors and windows throughout the nursery school day. These peaks and troughs were absent in the weekend O_3 concentration profiles of both the AFS classroom and control classroom, as exchanges between indoor and ambient air would have been limited over that period. This implies the primary source of O_3 in the AFS and control classroom was from intrusion from ambient air, as increases in O_3 concentrations over the weekend were very similar in both the in the AFS classroom AFS and control classrooms.

5.4 COLUMBIA MARKET NURSERY SCHOOL

DIFFUSION TUBE MONITORING RESULTS

5.4.1. Figure 5-6 shows the average NO_2 concentration in the AFS and control classroom from the six-month diffusion tube measurements at Columbia Market. The diffusion tube measurements show concentrations in the AFS and control room are broadly similar at 20µg/m^3, taking into account that diffusion tubes can have up to +-25% uncertainty.

Figure 5-6 - Columbia Market Diffusion Tube Monitoring Results - Average NO_2 (µg/m^3)

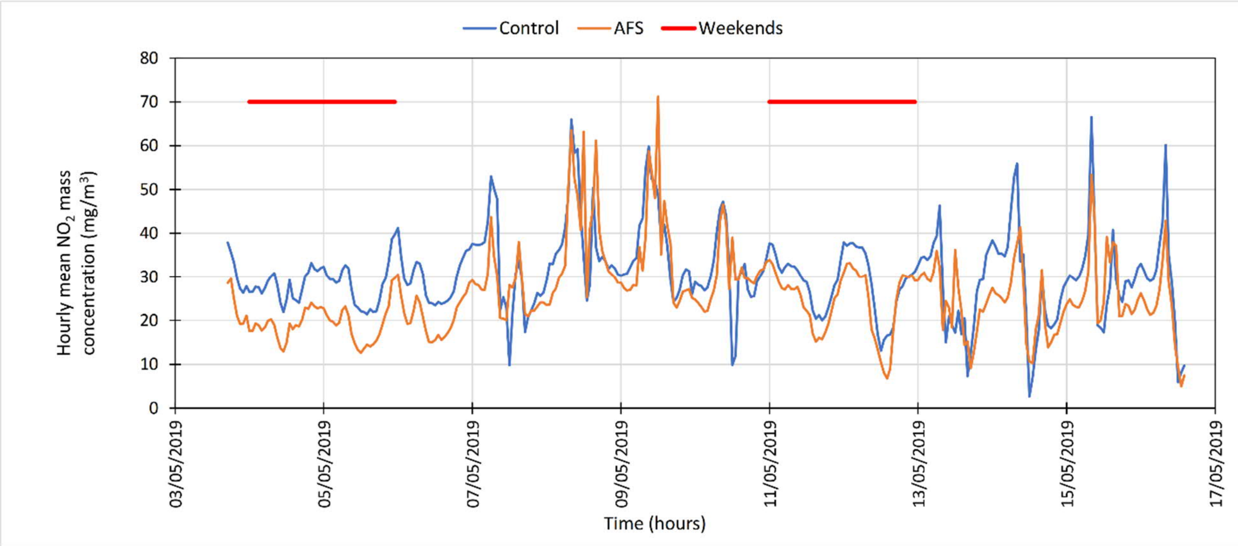


ZEPHYR SENSOR MONITORING RESULTS

NO_2 Measurements

5.4.2. The AFS installed at Columbia Market does have the function to specifically remove NO_x, and NO_2 Zephyr monitoring results (Figure 5-7) indicate differences exist between the AFS and control room NO_2 concentrations, with higher concentrations in the control room for the majority for the time. Peak NO_2 concentrations were limited during the weekend (4th to 5th May, and 11th to 12th May). The AFS classroom generally experienced lower NO_2 peak values than the control classroom, though over the whole sampling period, average concentrations were of a similar magnitude between the AFS and control classrooms.

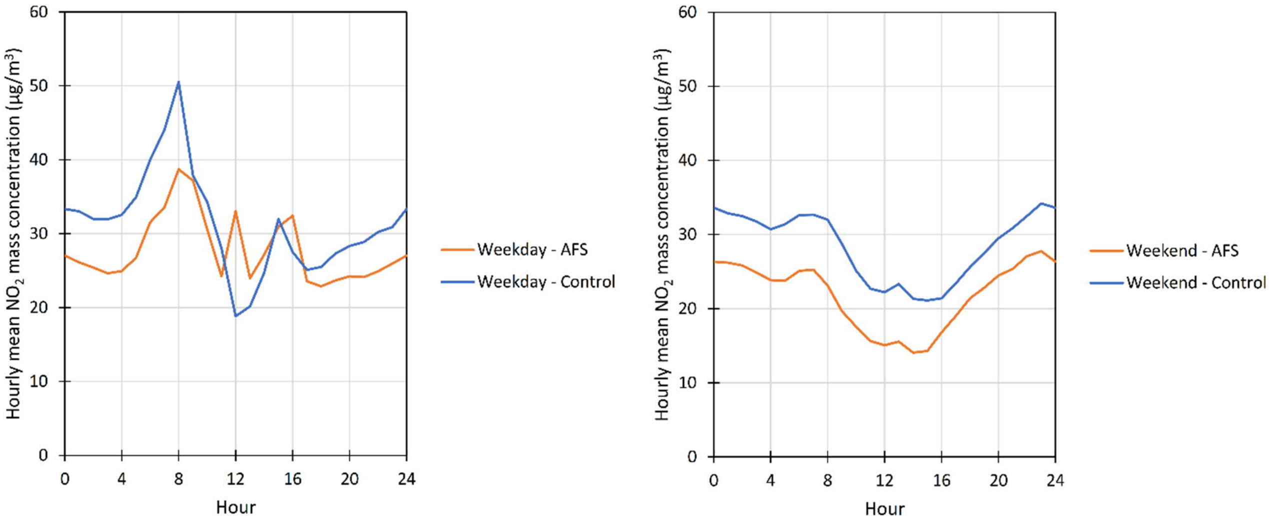
Figure 5-7 - Columbia Market Zephyr Sensor Monitoring Results NO_2 Concentration (µg/m^3)



5.4.3. Figure 5-8 indicates a difference between the AFS and control room NO_2 concentrations, with at times, higher concentrations in the control room. In the control room, concentrations rise to up to 50µg/m^3 between 07:00hrs and 10:00hrs, whilst NO_2 concentrations in the AFS room are below 50µg/m^3 over the same period. This rise in NO_2 concentrations during the morning period are likely to be associated with localised intrusion of street sourced air, through open doors and windows for both the AFS and Control room.

5.4.4. Weekend NO_2 concentrations in both rooms are lower than weekday concentrations. A noticeable trough in both AFS and control room NO_2 concentrations occurs between 09:00hr and 16:00hrs over the weekend. The area close to Columbia Market is a street market during this period, and the trough on NO_2 concentrations, may be as a result of road traffic restrictions in the area, brought about by the street market.

Figure 5-8 - Columbia Market Zephyr Sensor Hourly Average NO_2 Concentration (µg/m^3)



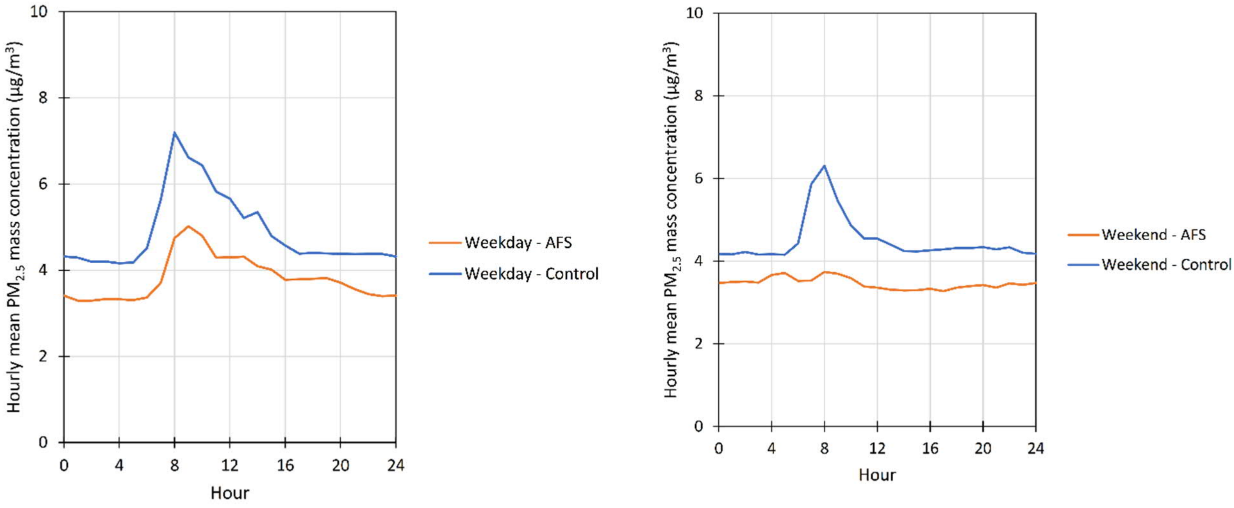
$PM_{2.5}$ Measurements

5.4.5. The control classroom appeared to have higher $PM_{2.5}$ concentrations across the whole monitoring period than the AFS class room as shown in Figure 5-9. In both rooms, concentrations were between 5 to 6 $\mu g/m^3$ on average.

5.4.6. A small peak in $PM_{2.5}$ concentrations can be seen during the morning in both the weekday AFS and control room measurements. This may be related to the movement of staff and children causing an increase in resuspended dust, as this feature is absent at the weekend AFS classroom sample, and lower in the control room weekend sample.

5.4.7. Weekend $PM_{2.5}$ concentrations in both rooms were lower than weekday concentrations, with the AFS classroom being lower still. This is likely due to both classrooms remaining unoccupied over the weekend.

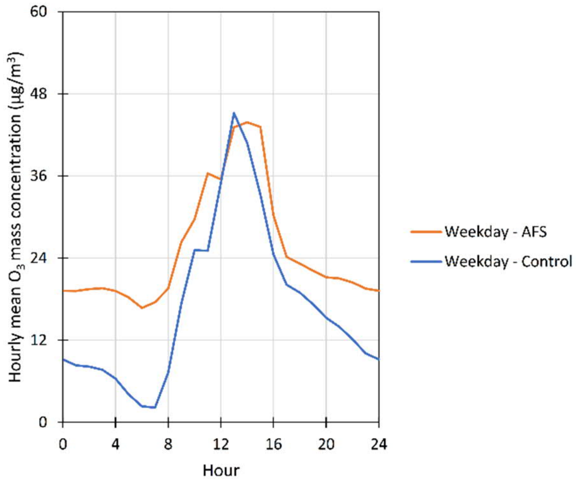
Figure 5-9 - Columbia Market Hourly Average $PM_{2.5}$ Concentration ($\mu g/m^3$)

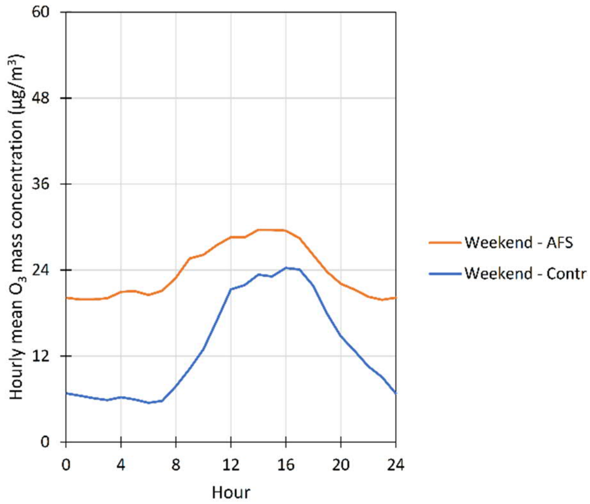


OZONE MONITORING RESULTS

5.4.8. Figure 5-10 shows the temporal trend in the 15-min average O_3 concentrations, measured in the AFS and control classrooms by the reference O_3 monitor.

Figure 5-10 - Columbia Market 15-min Average O_3 Concentration (µg/m^3)





5.4.9. Concentrations of O_3 in both the AFs and control classrooms were relatively low in both nursery classrooms, ranging between 6 to 27 µg/m^3. The range of O_3 concentrations in both classrooms were similar, with weekday AFS concentrations higher in the morning and control classroom higher in the weekday afternoon. The O_3 concentrations in the AFS classroom were higher than the Control classroom from a short period in week-day mornings, and higher throughout the weekend daytime periods. The daily changes in O_3 concentrations within both classrooms, with very low concentrations during evening and night-time periods confirms that the AFS is not a direct significant source of O_3, as concentrations would be expected to be consistently higher if they were an O_3 source. Ozone concentrations in both classrooms were well below the air quality objective concentration of 100µg/m^3.

5.4.10. Both week day and weekend concentrations follow similar temporal trends, with an increase in O_3 concentrations after 08:00hrs and peaking at round 16:00hrs before falling throughout the evening. These increases are co-incidental with photochemical production of ambient ozone. Increases in O_3 concentrations also occur within the control room during the weekday period. Weekend O_3 concentrations in both the AFS classroom and control classroom follow a similar pattern with slightly higher concentration within the AFS classroom. Peaks and troughs in O_3 concentrations were present for both the AFS classroom and control classroom during the weekday period, and these were less enhanced for the weekend period. These are likely to be associated with opening and closing of doors and windows throughout the nursery school day. The higher weekday concentrations imply the primary source of O_3 was from ambient air and not from the AFS.

5.5 RACHEL MCMILLAN NURSERY SCHOOL AND CHILDREN'S CENTRE

DIFFUSION TUBE MONITORING RESULTS

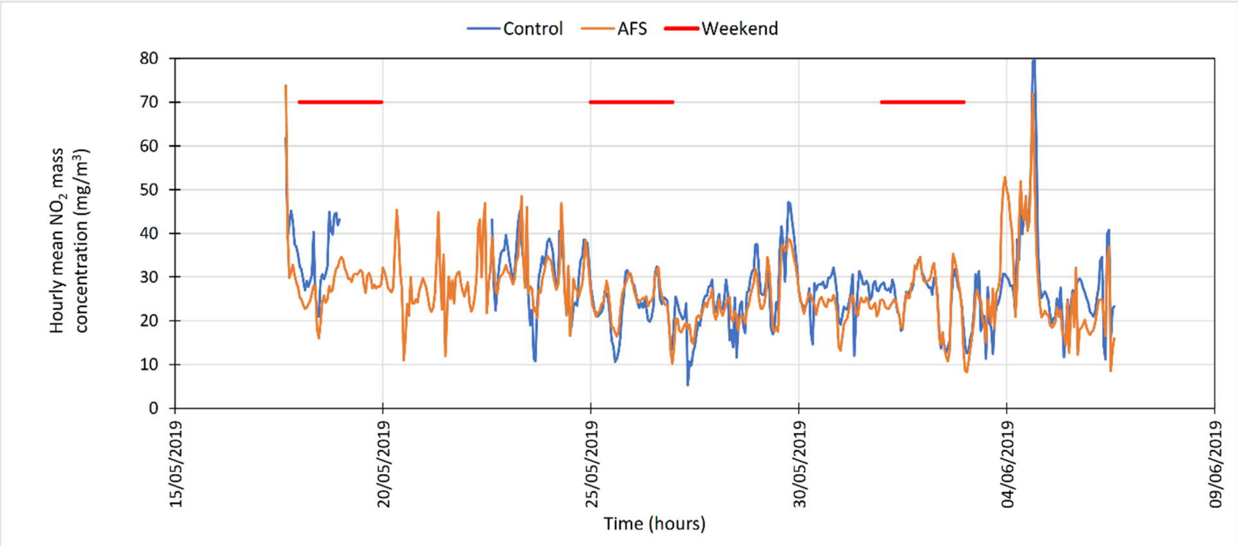
5.5.1. Of the six diffusion tube samples sent out to Rachel McMillan nursery only two were returned. Therefore, with such a low sample return, diffusion tube results from Rachel McMillan where considered to be unrepresentative of indoor air quality concentrations.

ZEPHYR SENSOR MONITORING RESULTS

NO_2 Measurements

5.5.2. The AFS installed at Rachel McMillan specifically removes NO_x, and Figure 5-11 indicates over the limited Zephyr monitoring period higher concentrations in the control room for the majority for the time. Peak NO_2 concentrations were limited during the weekend (18th to 19th May, and 25th to 26th May and 1st to 2nd June). The AFS classroom generally experienced lower NO_2 peak values than the control classroom.

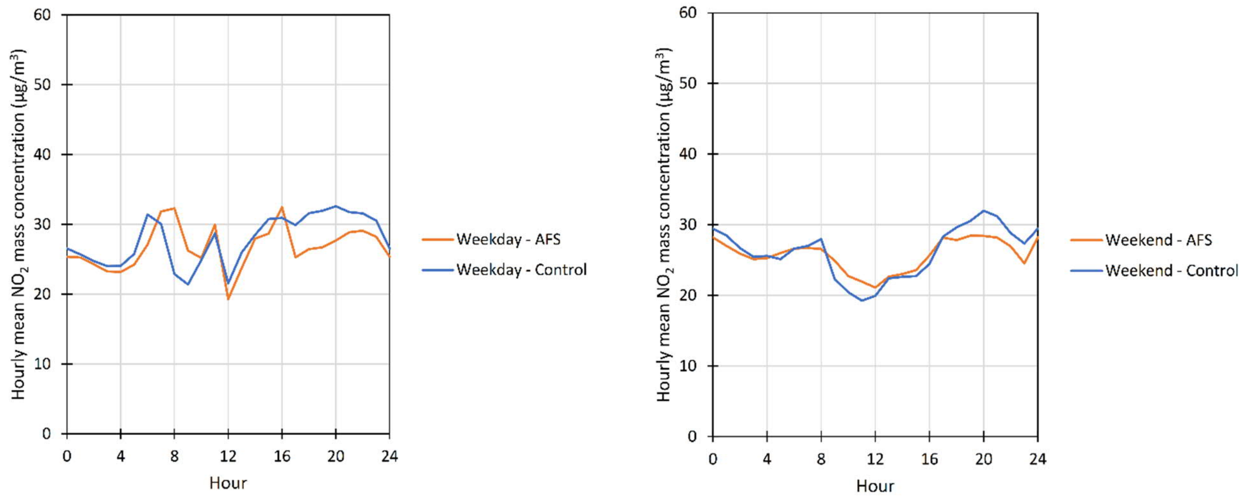
Figure 5-11 - Rachel McMillan Zephyr NO_2 Concentrations ($\mu g/m^3$)



5.5.3. Both AFS and control nursery classrooms weekday NO2 concentrations increase between 07:00hrs and 09:00hrs; around 11:00hr and after 15:00hr (**Figure 5-20**).

5.5.4. Whereas, over the weekend AFS and control classroom NO_2 concentrations remained broadly similar, increasing over the morning period and rising once again in the late afternoon, these changes in concentration were possibly due to increases in local road traffic movements during that time. Weekend NO_2 concentrations in both rooms are lower than weekday concentrations. A noticeable dip in control room concentrations occurs at 16:00hrs during the week and at the weekend. This coincides with the end of the Nursery school day, and is likely to be associated with the closing of external doors and windows.

Figure 5-12 - Rachel McMillan Zephyr Hourly Average NO_2 Concentration (µg/m³)



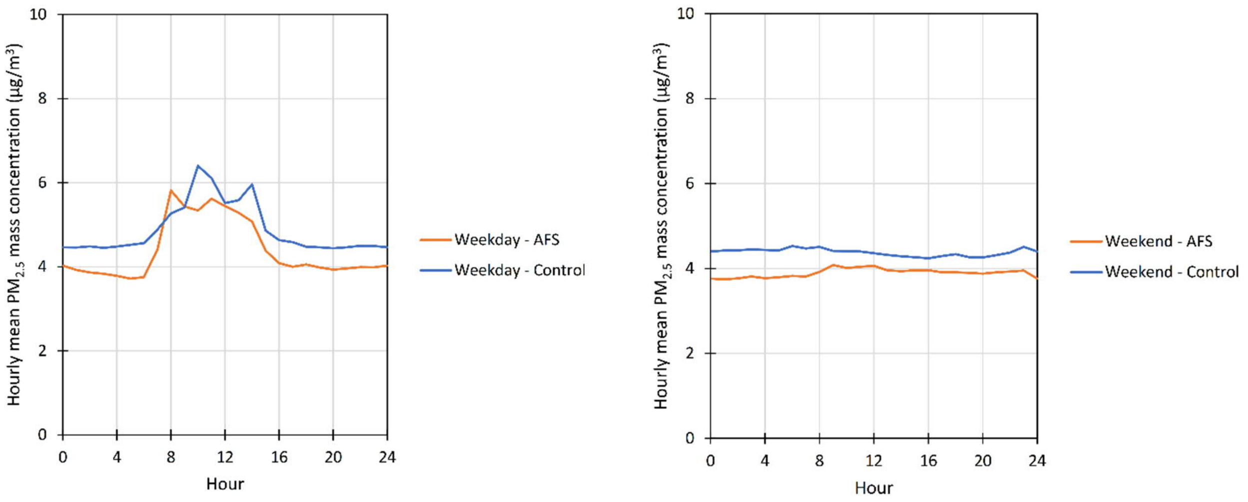
$PM_{2.5}$ Measurements

5.5.5. The control classroom appeared to have higher $PM_{2.5}$ concentrations across the whole monitoring period than the AFS class room as shown in Figure 5-13. In both rooms, midweek concentrations were around 5 µg/m³.

5.5.6. A rise in $PM_{2.5}$ concentrations can be seen during the morning in both the weekday AFS and control room measurements. This may be related to the movement of staff and children causing an increase in resuspended dust and dust generating activities over the nursery school, as $PM_{2.5}$ concentration subside in the late afternoon, as the nursery empties of staff and pupils.

5.5.7. Weekend $PM_{2.5}$ concentrations in both rooms were lower than weekday concentrations, with no peak concentrations, as both classrooms remain unoccupied over the weekend.

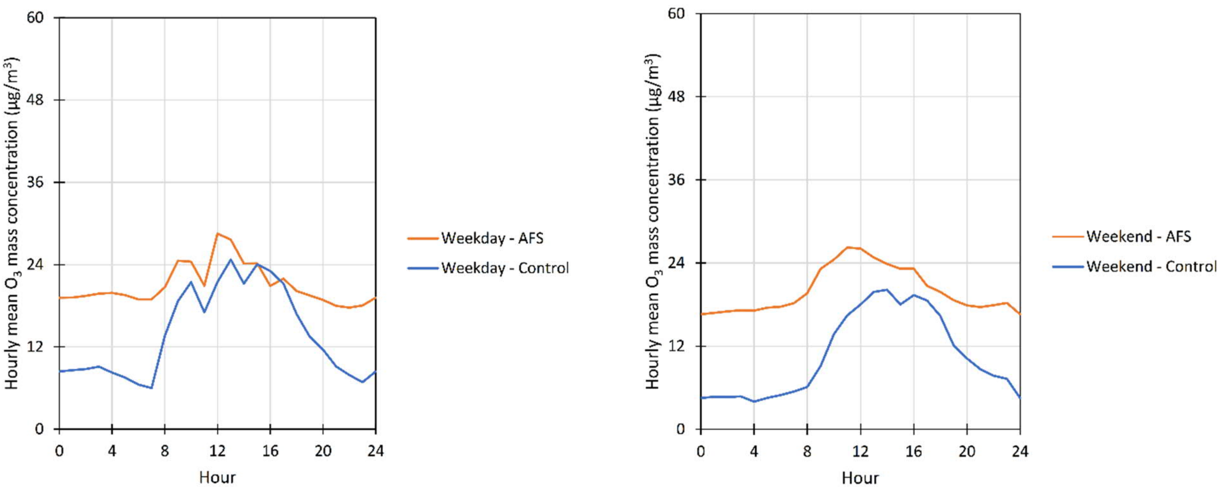
Figure 5-13 - Rachel McMillan Zephyr Hourly Average $PM_{2.5}$ Concentration (µg/m³)



OZONE MONITORING RESULTS

5.5.8. Figure 5-14 shows the temporal trend in the 15-min average O_3 concentrations, measured in the AFS and control classrooms by the reference O_3 monitor.

Figure 5-14 Rachel McMillan 15-min Average O_3 Concentration (µg/m^3)



5.5.9. Concentrations of O_3 in both the AFs and control classrooms were very low in both nursery classrooms, ranging between 2 to 13µg/m^3. The range of O_3 concentrations in both classrooms were similar, with weekday AFS concentrations higher in the morning and afternoon, though not significantly falling in concentration during evening and night-time periods. This would have been consistent with there being a low level source of O_3 within the AFS classroom during both evening and weekends. Ozone concentrations in both classrooms were well below the air quality objective concentration of 100µg/m^3.

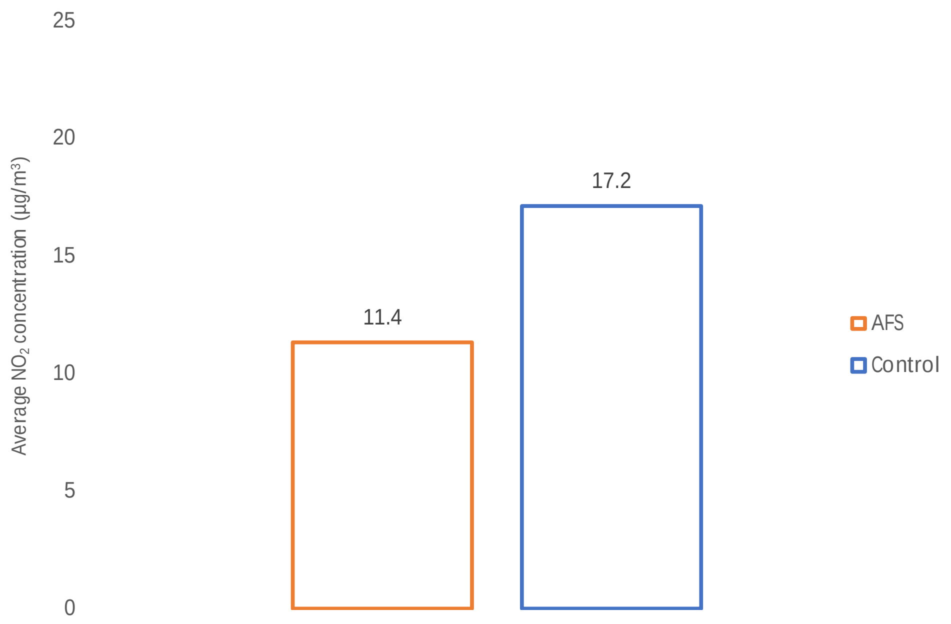
5.5.10. Both week day and weekend concentrations follow similar temporal trends, with an increase in O_3 concentrations after 08:00hrs and peaking at round 16:00hrs before falling throughout the evening. These increases are co-incidental with photochemical production of ambient ozone. Increases in O_3 concentrations also occur within the control room during the weekday period. Weekend O_3 concentrations in both the AFS classroom and control classroom. Peaks and troughs in O_3 concentrations were present for both the AFS classroom and control classroom during the weekday period, and though these were still present in the weekend sample, they were less pronounced. There was no significant difference between and midweek and weekend O_3 concentrations. This implies that for both the AFS and Control classroom intrusion of external air could possibly be occurring over the weekend due to poor building insulation allowing external air to intrude inside.

5.6 PEMBURY HOUSE NURSERY SCHOOL

DIFFUSION TUBE MONITORING RESULTS

5.6.1. Figure 5-15 shows the average NO_2 concentration in the AFS and control classroom from the six-month diffusion tube measurements at Pembury House. The diffusion tube measurements show NO_2 concentrations in the two rooms were quite different. Concentrations in the AFS room were 11µg/m^3 and almost one and half times greater (17µg/m^3) in the control room.

Figure 5-15 - Pembury House Diffusion Tube Monitoring Results - Average NO_2 (µg/m³)

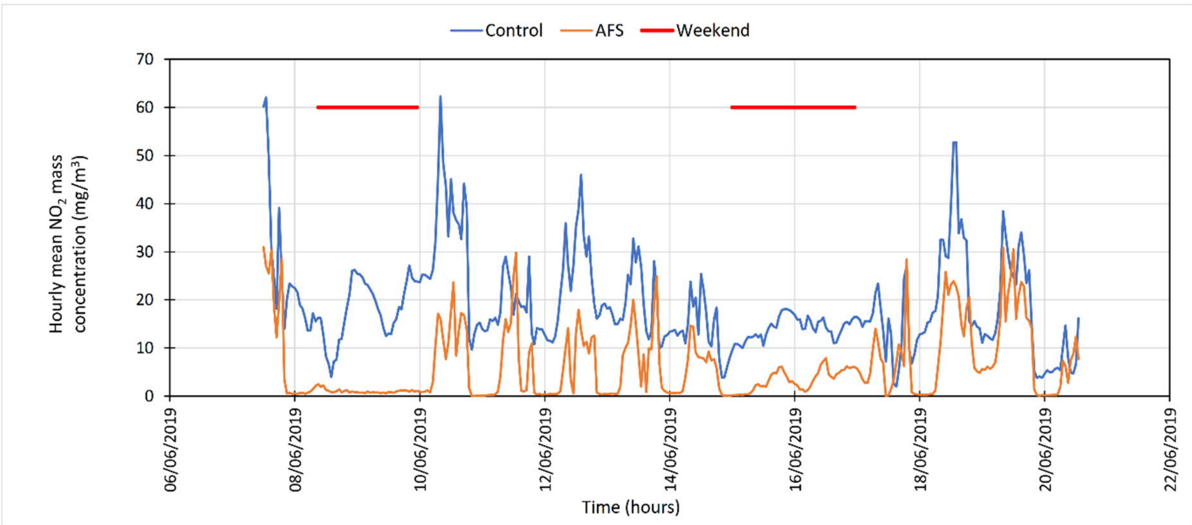


ZEPHYR SENSOR MONITORING RESULTS

NO_2 Measurements

5.6.2. The AFS installed at Pembury does have the function to specifically remove NO_x. Results from monitoring of NO_2 using the Zephyr, illustrated in Figure 5-16, indicate higher NO_2 concentrations in the control classroom over the AFS nursery classroom. Peak NO_2 concentrations were limited during the weekend (8th to 9th June, and 15th to 16th June). The AFS classroom experienced lower NO_2 peak values than the control classroom.

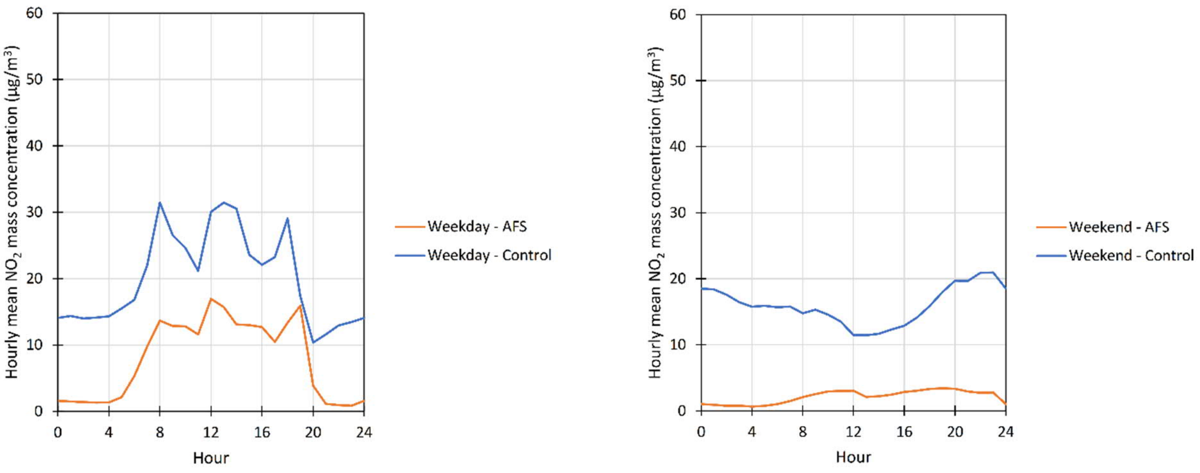
Figure 5-16 - Pembury House Zephyr Sensor Monitoring Results



5.6.3. Figure 5-17 indicates that the control room, weekday concentrations briefly rise above 30µg/m³ between 07:00hrs and 08:00hrs, whilst concentrations remain below 20µg/m³ in the AFS room over the whole day. A clear pattern of NO_2 concentrations rising in the morning, lunchtime and late afternoon can be seen in both the control and AFS classrooms. These rises in NO_2 concentrations are likely to a combination of children arriving and leaving, with doors opening resulting in intrusion of street sourced air, as well as an outcome of localised vehicle emissions during those periods.

5.6.4. Weekend NO_2 concentrations in both rooms are lower than weekday concentrations, with no notable diurnal pattern of NO_2 concentrations, with NO_2 concentrations lower in the AFS classroom over the weekend than the control classroom.

Figure 5-17 - Pembury House Zephyr Hourly Average NO_2 Concentration ($\mu g/m^3$)



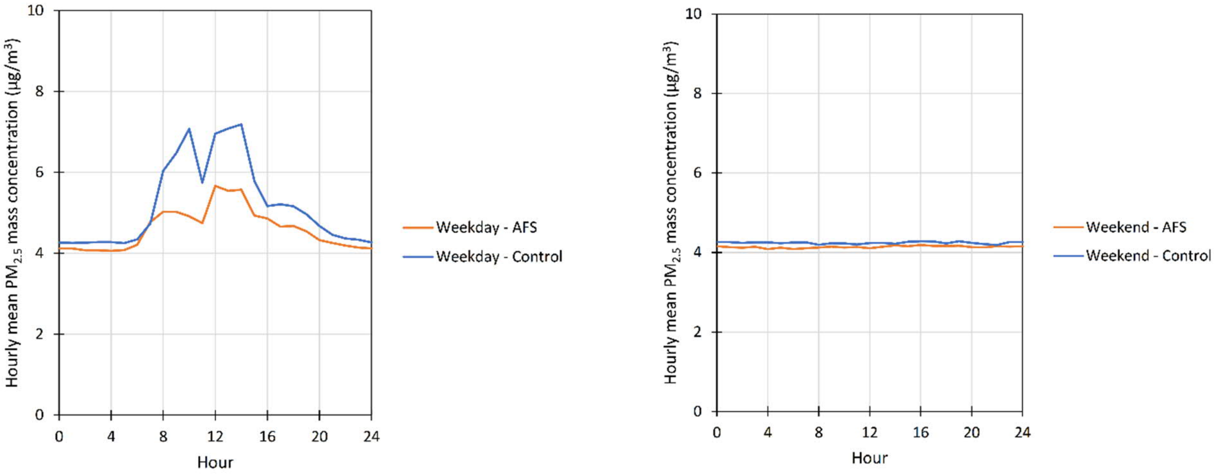
$PM_{2.5}$ Measurements

5.6.5. The control classroom appeared to have higher $PM_{2.5}$ concentrations across the whole monitoring period than the AFS class room as shown in Figure 5-18. In the control classroom midweek concentrations were around 6 $\mu g/m^3$, whereas in the AFS classroom midweek concentrations were lower at $5 \mu g/m^3$.

5.6.6. A rise in $PM_{2.5}$ concentrations can be seen during the morning in both the weekday AFS and control room measurements. This may be related to the movement of staff and children causing an increase in resuspended dust and dust generating activities over the nursery school, as $PM_{2.5}$ concentration subside in the late afternoon when the nursery empties of staff and pupils.

5.6.7. Weekend $PM_{2.5}$ concentrations in both rooms were lower than weekday concentrations, with no peak concentrations, as both classrooms remain unoccupied over the weekend.

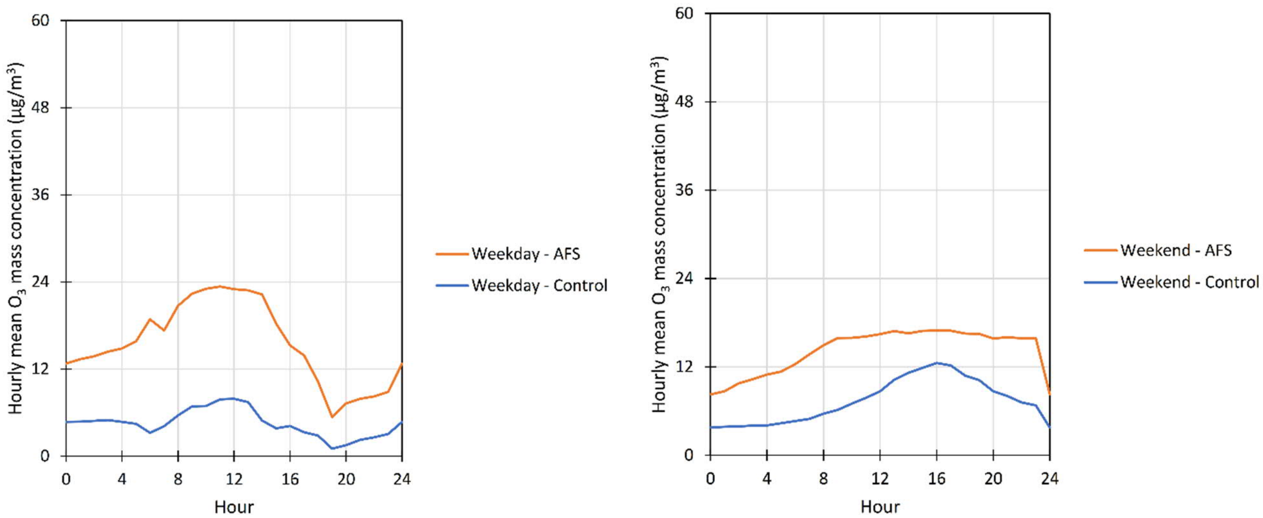
Figure 5-18 - Pembury House Zephyr Hourly Average Hourly Average $PM_{2.5}$ Concentration (µg/m³)



OZONE MONITORING RESULTS

5.6.8. Figure 5-19 shows the temporal trend in the 15-min O_3 concentrations, measured in the AFS and control classrooms by the reference O_3 monitor.

Figure 5-19 - Pembury House 15-min Average O_3 Concentration (µg/m³)



5.6.9. Concentrations of O_3 in both the AFs and control classrooms were very low in both nursery classrooms, ranging between 3 to 10µg/m³. The range of O_3 concentrations in both classrooms varied, with weekday AFS concentrations higher in the morning and afternoon, whereas control classroom concentrations were largely similar throughout the monitoring period. Ozone concentrations in both classrooms were well below the air quality objective concentration of 100µg/m³.

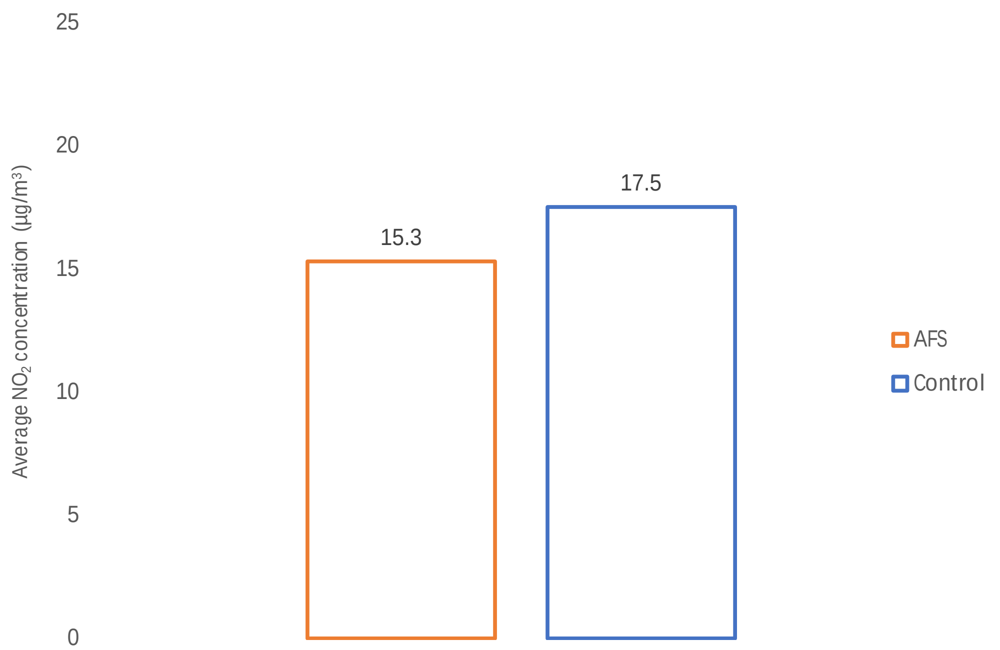
5.6.10. The O_3 concentrations in the AFS classroom were observed to rise shortly after 08:00hrs and peaking at round 16:00hrs before falling throughout the evening. These increases are co-incidental with photochemical production of ambient ozone. Though, generally O_3 concentrations were higher within the control classroom than the AFS classroom. There was no significant difference between and midweek and weekend concentrations for the control classroom, though O_3 concentrations in the AFS classroom were much lower over the weekend, implying that the midweek source of ozone was via intrusion of street sourced ambient air, and not the AFS.

5.7 THOMAS CORAM CENTRE

DIFFUSION TUBE MONITORING RESULTS

5.7.1. **Figure 5-20** shows the average NO_2 concentration in the AFS and control classroom from the six-month diffusion tube measurements at Thomas Coram. The diffusion tube measurements show concentrations in the AFS and control room are broadly similar at around 16µg/m^3.

Figure 5-20 – Thomas Coram Diffusion Tube Monitoring Results - Average NO_2 (µg/m^3)



ZEPHYR SENSOR MONITORING RESULTS

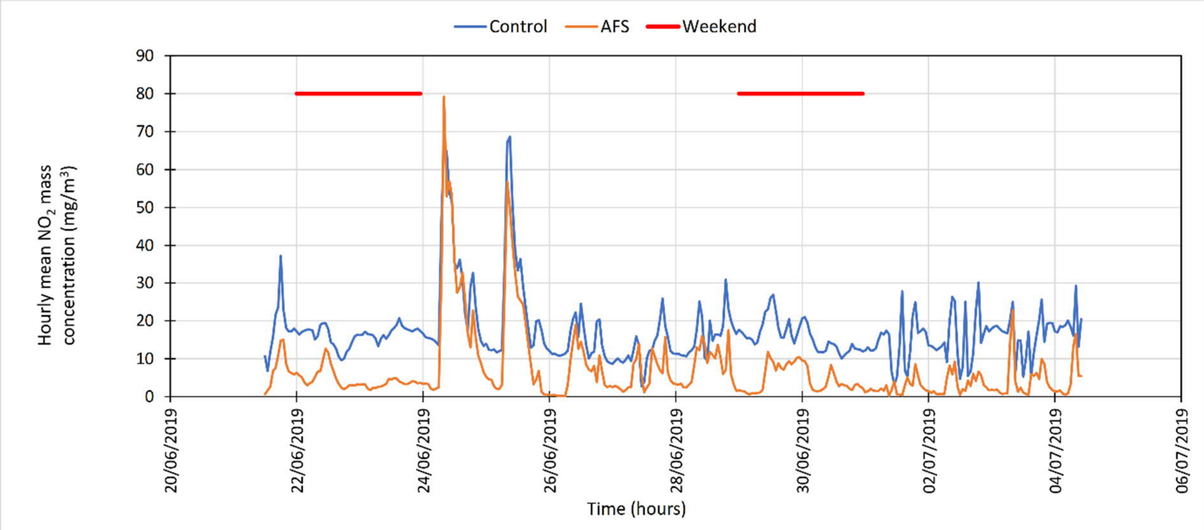
NO_2 Measurements

The AFS installed at Thomas Coram did not have the function to specifically remove NO_x. Results from monitoring of NO_2 using the Zephyr, illustrated in

Figure 5-21, indicates higher NO_2 concentrations in the control classroom over the AFS nursery classroom. Peak NO_2 concentrations were limited during the weekend (22nd to 23rd June, and 29th to 30th June). The AFS classroom experienced lower NO_2 peak values than the control classroom.

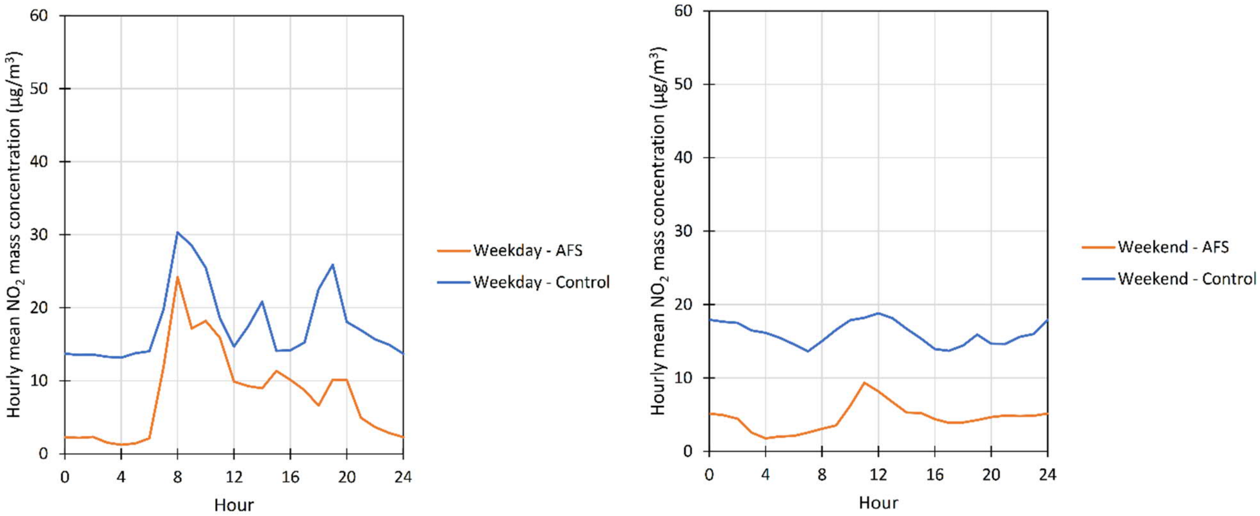
5.7.2. Weekend NO_2 concentrations in both rooms are lower than weekday concentrations, with no notable diurnal pattern of NO_2 concentrations. NO_2 concentrations were lower in the AFS classroom over the weekend than the control classroom.

Figure 5-21 - Thomas Coram Zephyr Monitoring Results Hourly Average NO_2 Concentration ($\mu g/m^3$)



5.7.3. Figure 5-22 illustrates the average control room, weekday concentrations rose up to 30µg/m³ between around 08:00hrs, whilst concentrations remained below 25µg/m³ in the AFS room over the whole day. There was a trend of NO_2 concentrations rising in the morning in both control and AFS classrooms, and in late afternoon within the control classroom only. These rises in NO_2 concentrations are likely to a combination of children arriving and leaving, with doors opening resulting in intrusion of street sourced air, as well as an outcome of localised vehicle emissions during those periods.

Figure 5-22 - Thomas Coram Zephyr Monitoring Results Hourly Average NO_2 Concentration ($\mu g/m^3$)



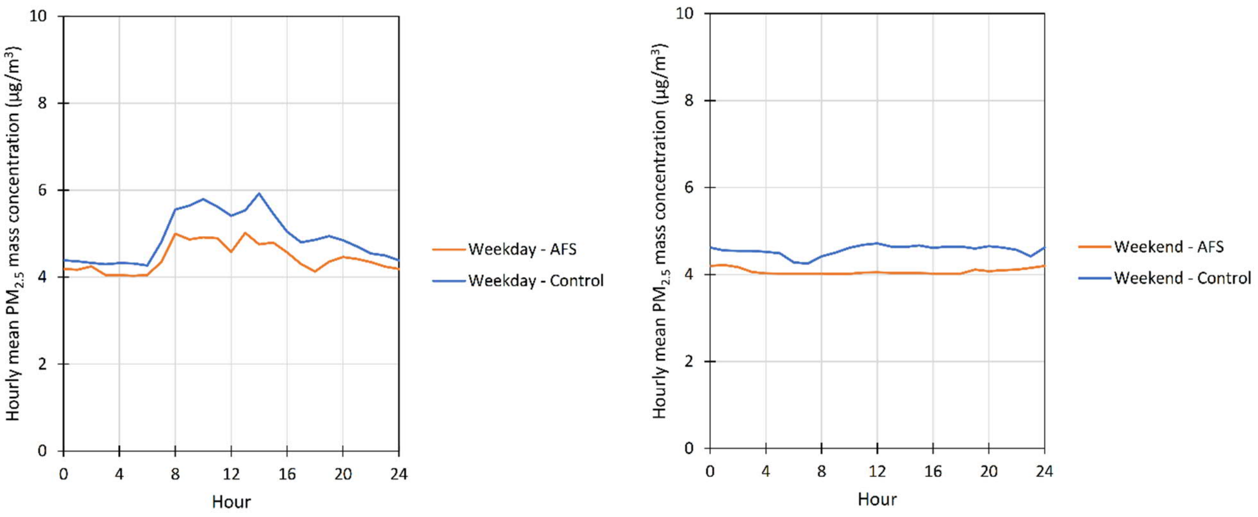
$PM_{2.5}$ Measurements

5.7.4. The control classroom appeared to have higher $PM_{2.5}$ concentrations across the whole monitoring period than the AFS class room as shown in Figure 5-23. In the control classroom midweek concentrations were around 5 µg/m^3, whereas in the AFS classroom midweek concentrations were lower at 4.5µg/m^3.

5.7.5. A rise in $PM_{2.5}$ concentrations can be seen during the morning in both the weekday AFS and control room measurements. This may be related to the movement of staff and children causing an increase in resuspended dust and dust generating activities over the nursery school, as $PM_{2.5}$ concentration subside in the late afternoon, as the nursery empties of staff and pupils.

5.7.6. Weekend $PM_{2.5}$ concentrations in both rooms were lower than weekday concentrations, with no peak concentrations, as both classrooms remain unoccupied over the weekend.

Figure 5-23 - Thomas Coram Zephyr Monitoring Results Hourly Average $PM_{2.5}$ Concentration (µg/m^3)



OZONE MONITORING RESULTS

5.7.7. No O_3 monitoring was undertaken at Thomas Coram.

5.8 DOROTHY GARDNER CENTRE

DIFFUSION TUBE MONITORING RESULTS

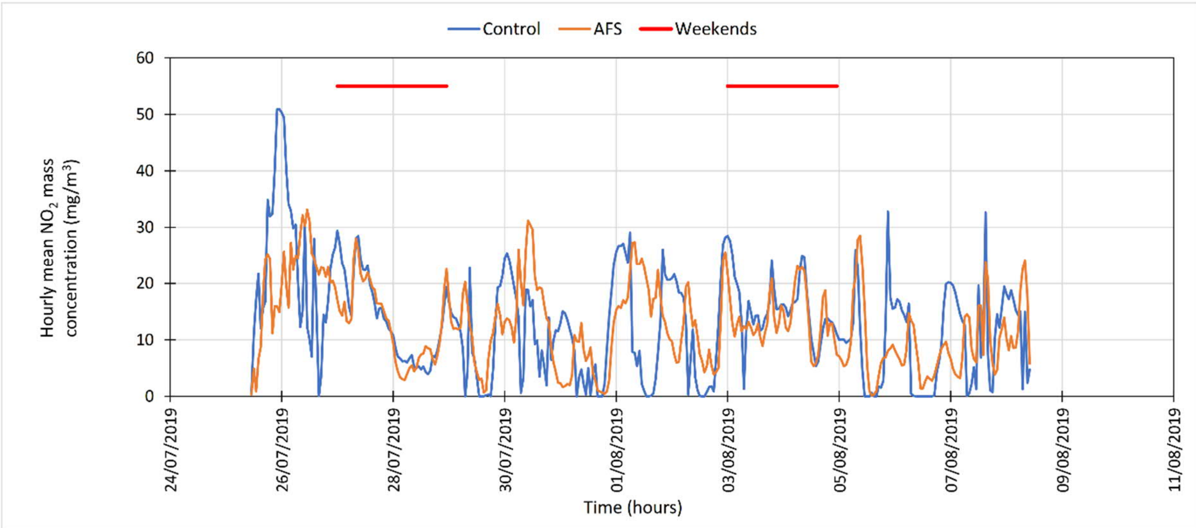
5.8.1. Of the six diffusion tube samples sent out to Dorothy Gardner nursery only three were returned. Therefore, with such a low sample return, diffusion tube results from Dorothy Gardner where considered to be unrepresentative of indoor air quality concentrations.

ZEPHYR SENSOR MONITORING RESULTS

NO_2 Measurements

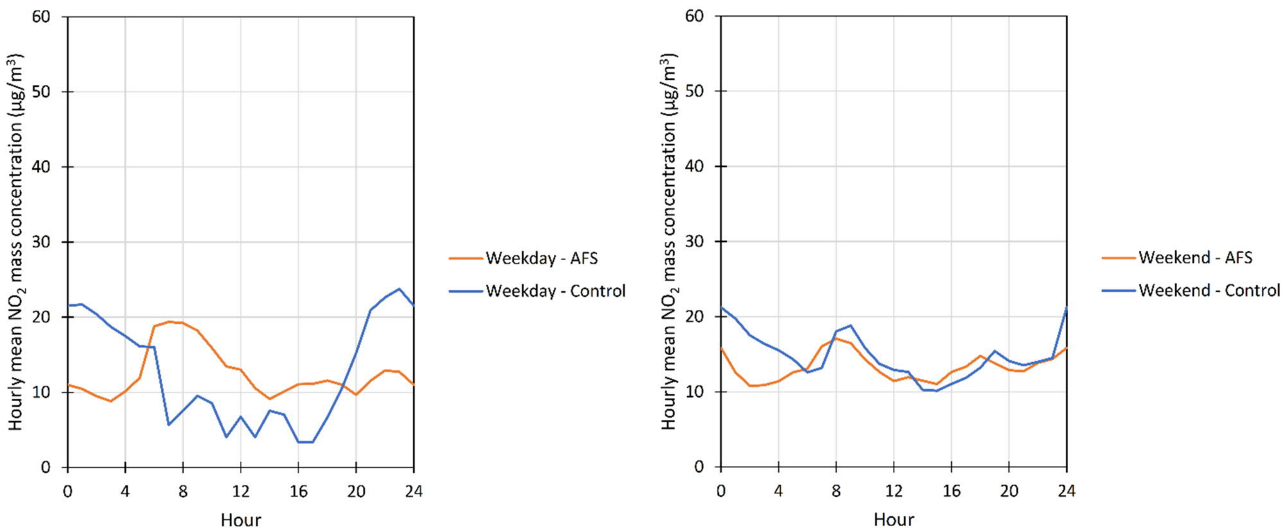
5.8.2. The AFS installed at Dorothy Gardner does have the function to specifically remove NO_x. Results from monitoring of NO_2 using the Zephyr, illustrated in Figure 5-24, indicate higher NO_2 concentrations in the control classroom during evening through to the early morning period, however NO_2 concentrations in the AFS nursery classroom were generally higher throughout the day.

Figure 5-24 - Dorothy Gardner Zephyr Sensor Monitoring Results



5.8.3. Figure 5-25 illustrates NO2 concentrations in the control room rose above 20µg/m3, NO2 concentrations remained below 20µg/m^3 in the AFS room over the whole period. Weekend NO2 concentrations in both rooms were similar to the AFS weekday concentrations, with no notable diurnal pattern of NO2 concentrations.

Figure 5-25 - Dorothy Gardner Zephyr Sensor Hourly Average NO_2 Concentration (µg/m^3)



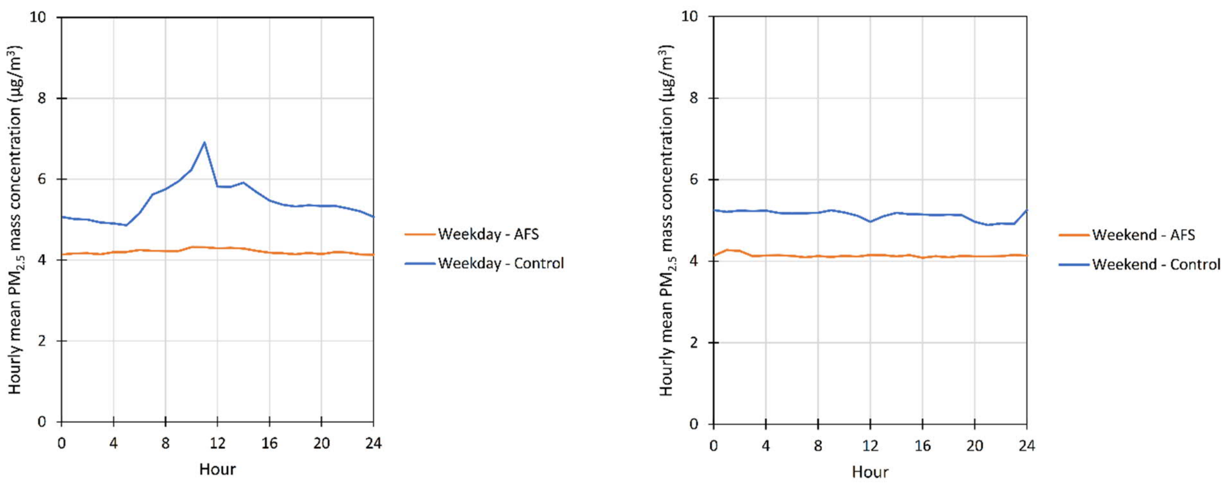
$PM_{2.5}$ Measurements

5.8.4. The control classroom appeared to have higher $PM_{2.5}$ concentrations across the whole monitoring period than the AFS classroom as shown in Figure 5-26. In the control classroom midweek concentrations were around 5 µg/m^3, whereas in the AFS classroom midweek concentrations were lower at around 4µg/m^3.

5.8.5. A rise in $PM_{2.5}$ concentrations can be seen during the morning in the control room measurements. This may be related to the movement of staff and children causing an increase in resuspended dust and dust generating activities over the nursery school, as $PM_{2.5}$ concentration subside in the late afternoon, likely a result of the nursery emptying of staff and pupils. No change in $PM_{2.5}$ concentrations was observed within the AFS classroom.

5.8.6. Weekend $PM_{2.5}$ concentrations in both rooms were marginally lower than weekday concentrations, with no peak concentrations, as both classrooms remain unoccupied over the weekend.

Figure 5-26 - Dorothy Gardner Zephyr Sensor Hourly Average $PM_{2.5}$ Concentration (µg/m^3)



OZONE MONITORING RESULTS

5.8.7. No O_3 monitoring was undertaken at Dorothy Gardner.

5.9 SUMMARY OF AFS MONITORING SURVEYS

5.9.1. Overall it can be seen that diffusion tube data indicated a positive reduction of NO_2 concentrations in 3 of the 6 nurseries when comparing the AFS classroom to the control classrooms. With diffusion tube results from Columbia Market, Nell Gwynn and Dorothy Gardner indicating that NO_2 concentrations were slightly higher in the AFS classroom than the control classroom. On average, the NO_2 concentrations from the diffusion tubes in the AFS classrooms were lower than the control classrooms by between 1 to 4µg/m^3. Generally, continuous sampling data generated from using the indicative Zephyr monitors confirmed that peak NO_2 concentrations were reduced in AFS classrooms in comparison to the control classrooms.

5.9.2. Zephyr data for $PM_{2.5}$ indicated concentrations were lower in AFS classrooms than control classrooms, with fewer peaks occurring in $PM_{2.5}$ concentrations in AFS classrooms than control classroom. For the monitoring period, all AFS were seen to be successful in reducing $PM_{2.5}$ concentrations in AFS classrooms.

5.9.3. Concentrations of NO_2 during the weekday sampling periods were higher when compared to the weekend periods for both AFS and control classrooms in most cases, this has been attributed to the intrusion of external ambient air.

5.9.4. Diurnal variations of NO_2 concentrations were observed during the midweek classroom Zephyr samples. Concentrations of NO_2 were often higher during morning arrival periods then the afternoon home-time periods, this could potentially be partly due to greater intensity of movement and opening/ closing of doors in the morning, as well as the higher concentration of NO_2 within the intruded external ambient air at that time of day.

5.9.5. Sampling results indicate that a significant source of NO_2 and O_3 was intrusion of external ambient air into the nursery classrooms, which occurred during midweek day-time periods, and was generally absence over the weekend. Limiting the intrusion of polluted air through closing doors and windows, as well as improving air tightness of nursery classroom, would therefore reduce both NO_2 and O_3 concentrations in the classrooms.

Figure 5-27 - Summary of the AFS Monitoring Survey Pollutant Reduction Detected *(Red negative reduction; White negligible; Green – positive reduction)*

Nursery	Effective NO_2 Reduction		Effective $PM_{2.5}$ Reduction	Effective Ozone Reduction
	Diffusion Tube	Zephyr		
Nell Gwynn	Negligible detected	Reduced peak hour NO_2 concentration in AFS classroom	Positive $PM_{2.5}$ reduction by approximately 0.8µg/m^3	Slight increase in O_3 detected
Columbia Market	Negligible detected	Reduced peak hour NO_2 concentration in AFS classroom	Positive $PM_{2.5}$ reduction by between 5 to 6µg/m^3.	Negligible difference detected
Rachel McMillan	N/A	Some minor reduction in AFS peak hour NO_2 in the afternoon, though minor increase in morning	Positive $PM_{2.5}$ reduction by approximately 0.3µg/m^3.	Negligible difference detected
Pembury House	Significant positive reduction with difference detected of 5.8µg/m^3	Significant NO_2 reduction in AFS throughout the day	Positive $PM_{2.5}$ reduction by up to 3µg/m^3	Positive O_3 reduction by between 4 to 6µg/m^3.

Nursery	Effective NO_2 Reduction		Effective $PM_{2.5}$ Reduction	Effective Ozone Reduction
	Diffusion Tube	Zephyr		
Thomas Coram	Successful positive reduction of 2.2µg/m^3 detected	Reduced peak hour NO_2 concentration in AFS classroom	Positive $PM_{2.5}$ reduction by between 0.2 to 1µg/m^3.	N/A
Dorothy Gardner	N/A	Reduction in NO_2 concentrations in AFS classroom	Positive $PM_{2.5}$ reduction by approximate 1 µg/m^3	N/A

5.9.6. Across the four nurseries that were monitored for O_3, a variety of results were displayed. In Pembury House the AFS classroom experienced a lower concentration of O_3 when compared to the control classroom. The other three nurseries displayed higher concentrations of O_3 in the AFS classroom when compared to the control classroom, though these differences in concentration are circa 2-5µg/m^3. Generally, the principle source of O_3 in all four nurseries monitored was considered to be intrusion of externally air, and not the AFS present within the classrooms.

5.9.7. Concentrations of NO_2, $PM_{2.5}$ and O_3 in all AFS and Control classrooms were all well below both ambient air quality limit values (Table 3-1) and occupational health standards (Table 3-2).

5.9.8. Average concentrations of $PM_{2.5}$ detected within nursery classrooms were all lower than 6 µg/m^3. This indicates for the monitoring period $PM_{2.5}$ concentrations in the classroom were well below WHO 2010 guidelines, though are likely to be slightly higher during periods when nursery classrooms were occupied.

5.10 ADDITIONAL FINDINGS

5.10.1. Clear differences were detected in the classroom concentrations of NO_2 and $PM_{2.5}$ between the midweek and weekend sampling periods. Generally, concentrations of NO_2 and $PM_{2.5}$ over the weekend were lower, with fewer peaks than the midweek samples. This may be due to the reduced influence of vehicle emissions upon the monitoring results, due to a lower proportion of intrusion of outside air entering the closed nursery classrooms at the weekend.

5.10.2. The reduction in both NO_2 and O_3 concentrations detected over the weekend periods at all nurseries confirms that the primary source of NO_2 during midweek periods is from a source external to the nursery. Increases in NO_2 and O_3 within nursery classrooms during the midweek period is most probably as a result of intruded vehicle emissions.

5.10.3. Higher incidents of $PM_{2.5}$ detected in midweek nursery classrooms may be as a result of externally intruded air, though, in addition classroom occupation and activity will also contribute to $PM_{2.5}$ concentrations.

5.11 NURSERY FEEDBACK

5.11.1. Participating nurseries were invited to provide feedback and comments regarding the AFS trial and their experiences, and this is summarised below:

Unobtrusive. No discernible noise and they haven't got in anyone's way. Wall-mounted and out of reach of the children.

Children and staff were initially curious about what it does and asked questions, but no longer noticed it.

The room smells better and feels fresher

Not noticed any particular difference in the feel of the room so will be interested to see the monitoring results.

We've had lots of interest from visitors and other schools/ nurseries wanting to take a look.

We experimented with the fan settings and it gets louder on the max setting, but still not that loud, and we only needed it on a low setting as it was a small room.

Installation was straight forward, did it over the weekend when no children were around. Completed in one day which is what we need – repeated visits would have been troublesome.

Children asked a few questions initially but they quickly fade into the background

Concerns over floor-standing units getting in the way and children being able to press buttons

Once they had set them up there was nothing for us to do really. They just did their thing.

Absolutely fine really. They weren't noisy, children initially asked about them as they could hear a noise and see a light on. Once we explained what they were just become part of the room.

The noise of the unit was very much in the background – you don't really notice it after a while.

No drawbacks – great we've got it.

It's been really good as we've ended up working them into our activities with the children about pollution, the environment and recycling.

Parents have been encouraged to see them and interested to know more and to see the results.

Installation was fine – we made sure it was done while the children were outside, provided a ladder and left them to it.

Anecdotally, feel there have been fewer asthma incidents where we have had to fetch asthma pumps.

We haven't noticed any real difference in the feel of the room.

Wheels on the unit should be lockable so children can't move it.

We had to tape the lid on to make sure children didn't remove it and put stuff in it.

Children put blu-tac in one of the filters as it was within reach – didn't seem to affect the machine though

The cleaners have unplugged it on occasions, there aren't enough sockets.

The unit was big and clunky – it took up a lot of space, and could not be pushed compactly into a corner as it needed space for air to move around.

We were nervous about having the plugged-in unit where the children could access it – but in fact the children seemed to ignore it.

Please can you recommend that the units be made smaller, quieter, able to be fixed high on a wall out of the way (like an air con unit)

Once they had set them up there was nothing for us to do really. They just did their thing.

One of the team who works daily in the room and has quite bad asthma. She felt better during the time the unit was switched on (not sure if this was a placebo effect though!)

Costs of replacement filters and ongoing maintenance - can you recommend that as Local Authorities have a duty of care towards the children in their nursery schools who are experiencing high levels of pollution, they agree to fund the ongoing expenses

5.12 AFS OPERATIONAL FINDINGS

5.12.1. The suppliers were free to specify the equipment and set-up to most effectively clean this space. The market cost of the AFS unit/s deployed and other key findings with regards AFS operation are summarised in the table below. This information was derived from publicly available information and data provided by the supplier regarding supply and maintenance costs.

Table 5-2 – Comparison of key AFS features, installation and operation

Features	Low	High	Average
Supply price	£750	£1,500	£1,000-1,200
Annual maintenance cost [11]	£150	£400	£250-300
Annual energy consumption cost [12]	£80	£185	£105
Noise level	25 dbA	68 dbA	41 dbA
PM filter life span	2,000 hours	8,760 hours	4,000-4,500 hours

[11] The average annual cost amongst the selected units is in the range of £250-300 assuming the units run for 8,760 hours a year. If we halve the operating hours, we have half of the maintenance costs per year.
[12] Average energy costs per year range from £105 if a unit runs 8,760 hours to £52.50 if runs for half of the hours; these figures are based on AFS running at full capacity. Lowering the operating speed results in reduced operating prices costs, but reduced performance per year.

Carbon activated filter life span	4,380 hours	8,760 hours	5,000-5,500 hours

Features	Observations
AFS Technologies	All of the selected AFS were fitted with filters and or the function to remove both PM and NO_x, with the exception of the IQair AFS, which for this trial was with fitted to remove PM.
AFS Deployment	The number of AFS installed in each classroom was proposed by the AFS supplier, and was largely dependent upon the size of the room, and the rate each AFS was able to treat the air. Camfil, IQair and Airlabs chose to install a single AFS unit in each classroom, whereas Radic8, AeraMax Professional and Blueair installed two AFS in each classroom.
Fan Setting	Each AFS was set up to run at a rate agreeable with the nursery, balancing the removal rate of polluted air against the noise of the unit. In addition, AFS treatment rates and airflow speeds were varied across operating hours. Typically, the AFS have at least three speed settings. Based on the information gathered the AFS typically run on a manual speed mode, unless additional remote controls are implemented.
Noise Levels	In terms of noise level, the units are no louder than a typical air conditioning unit (< 68 dBA). The noise levels are dependent on the fan speed of the AFS. The fan speed essentially determines how much ambient air is processed per hour. The higher the speed, the greater the noise levels.
Remote and automatic controls	Remote and automatic controls are typically available for each AFS unit (though sometimes at extra cost), and can be used for setting the fan speed of the AFS, and are particularly helpful for the wall-mounted units which can otherwise be hard to reach.
AFS Positioning	In some cases, the AFS units were positioned more centrally within rooms to improve air flow to the unit and aide performance, whilst in other cases the AFS had to be positioned in more compromised positions, due to the particular configuration and use of the space, and staff seeking to avoid them obstructing classrooms, or to be out of reach of the children. Wall mounted units generally received better feedback than floor mounted / standing units; due to the nature of a typical nursery environment.
Purchasing Arrangements	The supply price can be affected by factors such as: long term agreement on replacement filters' supply (in this case the initial price drops as an annual / monthly fee is charged to clients for maintenance components), number of units purchased (the more units are purchased, lower can be the price), additional filters fitted to the AFS increase the price as they deliver an increased removal capacity (for instance, some units can run either in PM removal only or combining PM removal and

	NOx). The supply price is also effected by purchasing directly from suppliers or via distributors; usually purchasing directly (where available) can reduce supply prices
Maintenance plans	Maintenance plans for the units are provided by the suppliers, although it is beneficial for a member of the nursery staff to also be familiar with the units and able to perform basic maintenance. Regular visual inspections of the AFS are advisable to identify any power supply problems and filter change alarms.

5.12.10. In the section below a summary is provided of the AFS used across the different nurseries.

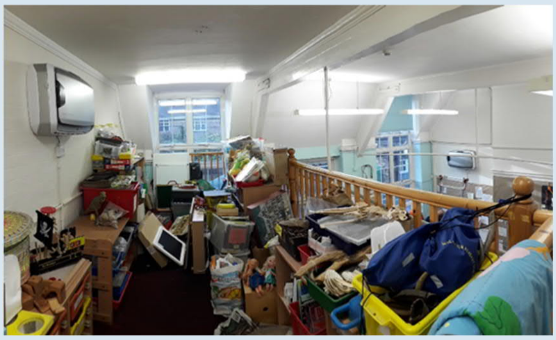
Camfil

5.12.11. Camfil installed their Air Cleaner CC 400 Concealed unit, which typically provides mechanical filtration using a high efficiency HEPA filter. As the unit can be also be fitted with a carbon filter, they opted to include this as well it can also remove NO_x. The unit was fitted to the wall.

Nursery	A
AFS	Camfil Air Cleaner CC 400 Concealed 
Capacity	0-410 m³/h
Quantity	1
Removal	Particulate + NO_x
Installation	Wall
Power input	170W (at max speed)
Filter	F7 and H13 as standard
Air purification area	Up to 120 m²
Dimensions	1,113 x 313 x 327 mm
Sound level	< 50 dB
Weight	41kg
Risk assessment provided	Yes

AeraMax Professional (Fellowes Brands)

5.12.12. AeraMax Professional installed two of their Aeramax 4 PureView units, as the room was relatively large due to the double-height ceilings. The units were fitted with a PM and NO_x filter to demonstrate their effectiveness in removing both pollutants. The units were fitted to the wall.

Nursery	B
AFS	AeraMax Professional (Fellowes Brands) - Aeramax 4 PureView 
Capacity	0-747 m³/h
Quantity	2
Removal	Particulate + NO_x
Installation	Wall
Power input	8-166W (min-max speed) per unit
Filter	HYBRID, 25mm Carbon, 25mm TRUE HEPA
Air purification area	Up to 130 m² each
Dimensions	497 x 881 x 228 mm
Sound level	< 68 dB (max speed)
Weight	15.1kg each
Risk assessment provided	Yes

IQAir

5.12.13. IQAir installed their IQAir SL unit, which provides mechanical filtration using a high efficiency HEPA filter. The unit was fitted on the floor but can be wall-mounted if required.

Nursery	C
AFS	IQAir SL 
Capacity	0-820 m³/h
Quantity	1
Removal	Particulate
Installation	Floor (though the unit can be wall mounted)
Power input	74W (at max speed)
Filter	HyperHEPA H11
Air purification area	Not indicated by IQAir as driven by air capacity
Dimensions	1,120 x 730 x 250 mm
Sound level	25 - 56 dBA
Weight	32kg
Risk assessment provided	Yes

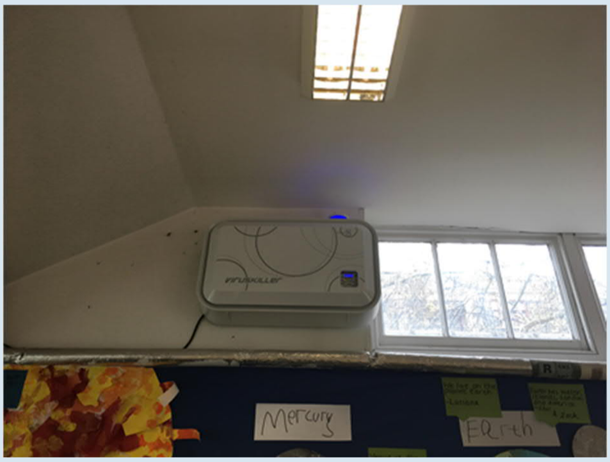
Blueair

5.12.14. Blueair installed two Blueair Classic 605 units fitted with an electrostatic filter, providing PM collection and a carbon activated filter for NO_x reduction. The units were floor standing units.

Nursery	D
AFS	Blueair Classic 605 
Capacity	0-850 m³/h
Quantity	2
Removal	Particulate + NO_x
Installation	Floor
Power input	100W (at max speed)
Filter	+ SmokeStop filter
Air purification area	Up to 72 m²
Dimensions	660 x 500 x 340 mm
Sound level	33 - 62 dB(A)
Weight	16kg
Risk assessment provided	Yes

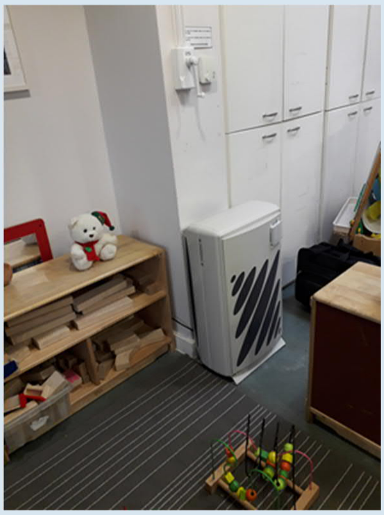
Radic8

5.12.15. Radic8 installed two Radic8 VK Blue units fitted with the typical Radic8 technology (PM, carbon activated, UV and titanium dioxide) configuration in order to prove their effectiveness to reduce the levels. Each of the units were mounted on the wall, with one at either end of the classroom.

Nursery	E
AFS	Radic8 VK Blue 
Capacity	0-240 m^3/h
Quantity	2
Removal	Particulate + NO_x
Installation	Wall
Power input	95W (at max speed)
Filter	HEPA (undisclosed class) + carbon
Air purification area	Up to 60 m^2
Dimensions	640 x 380 x 165 mm
Sound level	38 - 44 dB(A)
Weight	8kg
Risk assessment provided	Yes

Airlabs

5.12.16. Airlabs installed an Airbubbl unit that was bespoke and fitted with a PM and NO_x filter to demonstrate their effectiveness at reducing both pollutants. It has also an electrostatic precipitator fitted. The unit was fitted on the floor.

Nursery	F
AFS	Airlabs Airbubbl 
Capacity	300-1,200 m³/h
Quantity	1
Removal	Particulate + NO_x
Installation	Floor
Power input	125W (at max speed)
Filter	Electrostatic precipitator
Air purification area	Up to -- m²
Dimensions	468x303x840 mm
Sound level	38 - 51 dB(A)
Weight	30kg
Risk assessment provided	Yes

5.12.17. The table below provides an overview of the AFS units featured in the trial.

Table 5-3 – Overview of AFS Specifications

AFS	Camfil	IQAir	Blueair	Radic8	AeraMax Professional	Airlabs
Removal	PM and NOx	PM	PM and NOx	PM and NOx	PM and NOx	PM and NOx
Technology	▪ Mechanical filtration ▪ Carbon activated filter	▪ Mechanical filtration	▪ Mechanical and electrostatic filtration ▪ Carbon activated	▪ Mechanical and electrostatic filtration ▪ Carbon activated ▪ UV ▪ Titanium Dioxide activated	▪ Mechanical and electrostatic filtration ▪ Carbon activated	▪ Mechanical and electrostatic filtration ▪ Carbon activated
Number of units	1	1	2	2	2	1
Filtration capacity	0-410 m^3/h	0-820 m^3/h	0-850 m^3/h	0-240 m^3/h	0- 747 m^3/h	0-1,200 m^3/h
Power input per unit (max speed)	170W	74W	100W	95W	175W	125W
Control	Manual	Manual	Manual	Manual	Manual	Manual
Weight per unit	41kg	32kg	16kg	8kg	15kg	30kg
Location	Wall	Floor	Floor	Wall	Wall	Floor
Type of room	Classroom	Classroom	Classroom	Classroom	Classroom	Family Room

5.12.18. All AFS have been fitted with filters to remove PM and NO_x apart from the IQair unit, which can be fitted with NO_x filtration, but for the trial was fitted for PM filtration only.

5.12.19. The AFS' amount of air processed per hour varies. As a result, each supplier proposed a number of units (one or two) depending on the area where the AFS were installed. Camfil, IQAir and Airlabs installed one unit only. Radic8, AeraMax Professional (Fellowes Brands) and Blueair opted for two units

5.12.20. The AFS were set to run at the most convenient speed to balance noise levels, removal capacity and operating hours; the chosen speed was usually medium to high in terms of settings.

5.12.21. The energy consumption of the units does not depend necessarily on the capacity of the AFS. It is affected by the filters quality, unit's design, fans' and motors' efficiency

6

CONCLUSIONS AND NEXT STEPS

6 CONCLUSIONS AND NEXT STEPS

6.1 CONCLUSION FROM MONITORING AFS

6.1.1. The deployment of six AFSs in nurseries across central London have provided an indication of the performance of these types of systems to reduce indoor air pollutants within a busy classroom environment.

6.1.2. Typically, the AFS performed well in reducing $PM_{2.5}$ in all cases, and where relevant, were found to reduce NO_2 in the majority of cases.

6.1.3. In two particular cases the NO_2 reduction brought about by AFS was significant. In one case the NO_2 detected was negligible for both detection systems, both diffusion tube and Zephyr, though this AFS was effective in reducing $PM_{2.5}$ concentration in nursery classrooms.

6.1.4. As baseline concentrations of $PM_{2.5}$ were observed to be very low throughout all nursery control classrooms monitored, the effectiveness of each AFS to reduce particulate concentrations was constrained. An indoor environment with higher concentrations of ambient $PM_{2.5}$ would have allowed each AFS to provide a clearer demonstration its particulate removal effectiveness.

6.1.5. Considering the dynamic environment that a nursery classroom represents, with its constantly varying occupancy, and pupil movements, all of the AFS were able to demonstrate a positive impact upon the nursery indoor air quality, with reductions in $PM_{2.5}$, and in some cases, significant reduction in NO_2 concentrations in nursery classrooms.

6.1.6. Weekend monitoring at one of the nursery schools, Columbia Market, revealed that the absence of traffic in the immediate vicinity, resulted in a significant reduction in NO_2 concentrations over the weekend period. Confirming that indoor air quality is directly linked to emissions from local road traffic. Therefore, reducing intrusion of ambient air during busy rush-hour periods could lead to significant improvements in indoor air quality.

6.2 CONCLUSIONS FROM NURSERY FEEDBACK

6.2.1. The trial also found that the AFS units were suitable for installation and operation in a nursery environment, with the experience of the nurseries found to be largely positive, with most remarking that the units were unobtrusive in terms of their presence in the classrooms, with low levels of noise and minimal requirements for space meaning they quickly faded into the background.

6.2.2. There was criticism in one case that a unit was noisy, and that because it was required to be positioned away from the wall to allow air to move around it, it occupied a lot of space.

6.2.3. In general, the wall-mounted units were felt to be better suited to a nursery environment.

6.2.4. Some staff remarked that the air felt fresher in the rooms with AFS, or that the rooms smelt better, though others had not noticed any particular difference in the feel of the room, and were instead keen to be guided by the findings of the monitoring.

6.3 CONCLUSIONS FROM AFS TRIAL OPERATIONAL EXPERIENCE

6.3.1. Effective AFS performance can be dependent upon a number of factors, in addition to indoor pollutant concentrations, these include:

- Effective maintenance;
- Preservation of room atmosphere with minimal air changes per hour;
- AFS operating settings/ power supply monitored;

6.3.2. Poor maintenance could result in ineffective air-flow, blocked filters or faulty plasma cells, and lead to the AFS performing poorly, or even potentially degrading indoor air quality.

6.3.3. The effectiveness of an AFS often depends on minimising the intrusion of polluted air, and where a building has a significant proportion of polluted air intrusion, this needs to be taken into account when selecting the AFS type and size to ensure it is appropriately specified.

6.3.4. Regular visual inspections of the AFS are advisable to identify any power supply problems and filter change alarms, so the performance of the unit can be maintained.

6.4 RECOMMENDATIONS

6.4.1. AFSs could be duly considered amongst the range of measures available for addressing poor air quality outlined within the Toolkit of Measures[13] developed as part of this programme, where the conditions are right (i.e. poor levels of indoor air quality, particularly PM, and where there is limited scope to directly influence the sources of emissions or otherwise reduce exposure).

6.4.2. One indirect finding of this study has been that from weekend monitoring during a period of street closure, a significant reduction in NO_2 concentrations over the weekend period was detected. A recommendation arising from this would be exploration of street closures, managed traffic diversions away from nursery and other schools in order to improve indoor air quality within classrooms.

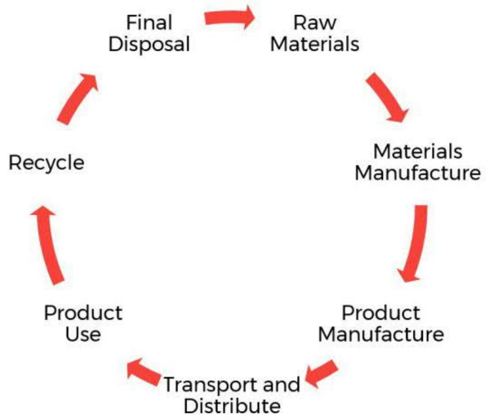
6.4.3. A benefit of AFS over some alternative measures is that they can typically be deployed very quickly, and should have an effect within hours. They are also relatively affordable, and whilst it would always be preferable to remove emissions at source, as opposed to retrospectively removing the pollutants from the air, measures to reduce emissions from passing traffic or surrounding buildings are often much longer term projects, and beyond the influence of the nurseries to directly affect.

6.4.4. This trial noted that the six nurseries where the trial took place were within ambient air quality limit values, despite the nurseries being in amongst the most polluted areas of London, with their windows and doors open regularly, which serves to underline the importance of establishing the baseline indoor air quality conditions to inform the requirements for an AFS. Though it is important to note that other studies have found indoor air pollutants such as $PM_{2.5}$ were often significantly higher inside classrooms than outdoors, and that there are no entirely 'safe' levels of exposure to harmful pollutants, and children would still benefit from further reductions. The low baseline concentrations of $PM_{2.5}$ will have constrained the ability of the AFS to reduce particulate concentrations, and further demonstrate their particulate removal effectiveness.

[13] Toolkit of Measures to Improve Air Quality at Schools
https://www.london.gov.uk/sites/default/files/school_aq_audits_-_toolkit_of_measures_dr_v3.3.pdf

6.4.5. It will be important for nurseries to consider not only the upfront costs of the AFS units, but also the ongoing operating and maintenance costs. We appreciate many of the nurseries are financially constrained, and the annual maintenance costs and energy consumption must be factored into any investment decisions. The operation of AFS will result in energy consumption and therefore potentially carbon emissions, subject to the generation source of the electricity.

Figure 6-1 - Life Cycle Assessment Flow Diagram



6.4.6. We would recommend a life cycle and energy assessment be undertaken to ensure the nurseries can fully account for the whole life costs of the unit in their budgeting, including the costs of energy consumption and maintenance (see **Figure 6-1**). These can be simple exercises undertaken by the nursery themselves, provided they know the filter price, operating hours and energy consumption of the unit.

6.4.7. These assessments will enable the nursery, potentially aided by borough council technical officers, to consider how the costs compare to alternative measures for improving indoor air, as in certain circumstances, an AFS might not be the most cost-effective solution. In the case of building refurbishment for example, an embedded centralised mechanical ventilation and filtration system may provide greater indoor air quality benefits than a standalone AFS.

6.4.8. Ultimately, whether a nursery should invest in an AFS is a very much an individual decision for each nursery and its staff. In our view, they certainly have a role to play, targeting particular classrooms or high-use areas where indoor air quality is poor (particularly in terms of PM where the AFS proved themselves to be most effective), where the need is pressing, and where there are few alternatives to stop the pollution at source. We would not advocate a blanket roll-out of AFS, mindful of the associated financial and environmental costs, and would encourage an evidence based approach, to ensure AFS are deployed effectively.

6.4.9. The Healthy Streets approach taken by Transport for London (TfL) and the Mayor of London promotes the creation of streets that are pleasant, safe and attractive, with a focus on reducing air pollution. This approach, alongside the application of the Toolkit of Measures developed as part of the Mayor's School Air Quality Audit Programme, remains key in reducing emissions at source.

Recommendations for future AFS users

6.4.10. Potential AFS users may need to consider the following items when selecting a prospective AFS and its supplier:

- What pollutants need to be targeted?
- What are the filters efficiency and removal capacity?
- Does the AFS use mechanical filtration, as this is the most established technology?
- Does the AFS use a HEPA filter, as these are strictly standardised?
- Is NO_x removal via activated carbon filter, as this is an established method?
- What does the installation entail, can it be completed when a classroom is not in use?

- What are the AFS maintenance, consumables and operational costs?
- Does the AFS come with a full maintenance plan?
- What is the noise impact of the AFS, is it suitable for the setting?
- What are the space requirements of the AFS, if children use the room does it need to be kept out of reach?

Recommendations for Government and other market regulators

6.4.11. The market research undertaken as part of this trial indicated that the efficiency of AFS are likely to improve over the coming years. In order to ensure safety and validity of the products currently offered by manufacturers, and to prepare for the large-scale deployment of AFS, the regulatory regime needs to catch-up with the AFS products being offered, and a set of AFS operational standards are now required, assisting both consumer and protecting supplier.

6.4.12. Currently, there are no efficiency standards for AFS as a whole, though standards exist for individual components, such as filters, fans, electric motors. Through standards and regulation AFS benchmarking and performance validity can then be independently undertaken.

6.4.13. Key recommendations to ensure future safety and performance standards for AFS would be:

- Government commissioned testing of AFS performance and safety is undertaken to determine risks, etc;
- A draft regulatory regime is drafted and put out to consultation with suppliers;
- To ensure appropriate application of AFS, suppliers need to provide clarity of when and where AFS can be best applied, with good cost to benefit ratio.

6.5 NEXT STEPS

6.5.1. It is important that we recognise the limitations of this trial, and that whist the monitoring of the selected AFS ‘in-situ’ has provided a snapshot of their performance when deployed within nursery classrooms.

6.5.2. However, in order to fully quantify the impacts of AFS upon indoor air quality a series of controlled tests need to be commissioned and undertaken by a third party. These will need to include testing using reference method monitoring instrumentation, and be conducted across low, medium and high pollutant concentrations. Testing will also need to include both primary air pollutants, such as NO_2, PM_{10}, $PM_{2.5}$ as well as secondary pollutants, such as O_3, VOCs and Formaldehyde, which can all be generated as by-products of AFS use.

6.5.3. A challenge in completing this research has been to make comparisons of the AFS units, as there are no common performance standards for the units as a whole (apart from CE marking and other general small power equipment electrical certifications).

6.5.4. For consumers to be able to make informed decisions, a common set of performance standards should be introduced. We also advocate the development of AFS design standards, with minimum performance requirements, certified under common testing criteria. In our view this would be especially beneficial for non-technical audiences.

6.5.5. The main stakeholders for potential standards' improvement are air filtration manufacturers associations, technical regulators in the air quality and human health sectors, governments and testing industry.

6.5.6. We would also advocate the development of AFS design standards setting minimum performance requirements, and "ad hoc" testing methodologies for stand-alone AFS; which would allow AFS's to be tested under the same conditions, and simple criteria to rank AFS in order of efficiency

6.5.7. We would also suggest that potential certifications for AFS regarding removal capacity under common testing criteria are established.

Appendix A

NURSERY ENVIRONMENTS -
EXPANDED WRITE-UPS

NURSERY ENVIRONMENTS

The position of each nursery in relation to notable emissions sources, such as heavily trafficked roads, and the volume of traffic was also considered, as summarised in the table below.

Daily Traffic Volumes around the Nurseries

Nursery	Proximity to Emissions Sources
Columbia Market	On a relatively busy road (8,300 vehicles per day)
Rachel McMillan	On a road, set back from main road, partially screened (12,900 vehicles per day)
Nell Gwynn	On a relatively busy road, and near a major road, partially screened (8,400 vehicles per day)
Pembury House	On a road, near main road (11,500 vehicles per day)
Thomas Coram	Set back from main roads, screened by buildings (6,000 vehicles per day)
Dorothy Gardner	On a minor road, set back and screened from more major roads (17,300 vehicles per day)

Note: Vehicles per day figures includes vehicles travelling on the core roads within a 200m radius of each nursery, based on the LAEI model traffic forecasting.

The environment and conditions for each of the nurseries participating in the trial were recorded in detail at the commencement of the trial, and are summarised below:

Columbia Market

The nursery site is part of the former Columbia Market and the building and surrounding railings and gate piers are grade 2 listed. The nursery has approximately 80 pupils and 20 staff.

The nursery plot sits at the corner of Columbia Road and Pelter Street. The nursery building is sited close to the boundary with Columbia Road. It is single storey and forms a square ring around a central courtyard.

The nursery has listed building status, with three sides of the building dates from the time of the original Columbia Market building and are of wooden construction, with large single glazed wooden windows on all sides that can be opened. The fourth side of the building was constructed in the last decade, and is of modern building standards and insulation levels. The original building facade is timber shiplap. The auditor was informed that upon removing the internal wall covering, it was discovered there was no insultation.

The playground is located in the northwest corner of the site, and has a 4-metre-tall metal chain link fence. There are a number of large trees and bushes planted along this boundary, but it is otherwise largely exposed to vehicle emission from Pelter Street.

There are three large class rooms for children that surround the courtyard area, and open on to the large playground. The classrooms have high vaulted ceilings and single glazed windows. It was informed that the rooms get very hot in the summer months, and very cold in the winter, depending on the outside ambient temperature. The children typically free-flow between the classroom and the playground throughout the day. The doors to the grounds do not have free-flow 'butchers' curtains to retain heat.

The nursery is reliant on natural ventilation through opening doors and windows, and the limited insulation, high ceilings and large windows will result in greater heat loss, and so potentially increased run times by the nurseries boilers, and therefore greater emissions. It also results in higher temperatures during warmer weather, requiring windows/doors to be opened and so greater exposure.

The schools heating and hot water is provided by two gas boilers. One is under 10 years old and the second is around twenty years old. Both are regularly serviced. The flues exhaust above roof height in the far corner of the plot at the junction of Columbia Road and Pelter Street. The heating has been added to in a piecemeal fashion over the year, and is not performing effectively. Heat is not traveling to the newest section of the building. The nursery has installed blinds to lessen solar gain in the summer, and some rooms on the Columbia Road elevation have heat exchanges for cooling purposes.

The school kitchen does not have gas appliances. The cleaning chemicals are kept in a room off the kitchen where there is no access for children. Most floor coverings are laminate and furniture is of engineered wood.

Summary of AFS and control rooms and trial conditions:

- 2 wall-mounted AFS deployed in the Sunflower classroom - mid-sized classroom with pitched roof (approximately 56.6m^2). Naturally ventilated with open windows. External doors in occasional use. Approximately 6-20 children in the classroom, and 1-3 staff.
- Unit operation settings – continuous operation (24 hours), fan speed 3
- The control room was Bluebell classroom, which is comparable with Sunflower classroom.

The baseline air quality monitoring results for Columbia Market were as follows:

- NO2 concentrations were found to be highest at the roadside (44.1µg/m^3), with local road traffic emissions contributing significantly to roadside concentrations. In each month, the measured NO2 concentrations exceeded the annual mean NO2 national Air Quality Objective (AQO) of 40µg/m^3.
- NO2 concentrations fall to 30.52µg/m^3 in the playground, which is partially screened from traffic by fencing and some trees and shrubs. Concentrations at the nursery entrance are higher (43µg/m^3) than the playground.
- Inside the nursery, concentrations both sit above and below external concentrations. During the second month, indoor levels rose above playground concentrations by between 7-9 µg/m^3.
- The NO2 I/O ratio was 0.79 at Columbia Market Nursery School, indicating that uncontrolled infiltration rates are at the higher range of the spectrum, and that the building offers only a limited level of protection to its occupants than a more airtight building.
- Volatile Organic Compounds (VOCs) were found to be 433.0 µg/m3, which was a very high concentration. Within the December samples the majority of VOCs detected were hydrocarbons and likely to be street-sourced pollutants derived from products of partial combustion. In the

March sample VOC chemical species were identified as being likely to be indoor pollutants, and included fragrances, perfumes and alcohols, likely to be products derived from use of cleaning materials and solvents.

- Formaldehyde were found to be 3.69 µg/m3.

Rachel McMillan

Rachel McMillan Nursery School is located in South-East London and sits within the Borough of Greenwich. At the time of the audit the nursery had 105 full-time equivalent children, with the numbers increasing to about 160 children in the summer term.

The nursery entrance is located on McMillan Street, just south of the staggered junction of McMillan Street / Stowage / Deptford Green. The entrance leads to an outdoor area from which the classrooms (shelters) open onto and are accessed.

The school is heritage listed being constructed in the early 1900’s, with the classrooms split over a number of buildings. The classrooms are known as shelters.

Shelters 1, 2 and the family room are located in the middle of the site. Shelters 3, 4, 6, the offices and community room face externally onto the road network. The external buildings have windows which open into the road, however they are not opened as they are broken. Shelter 5 is located to the rear of the site. It is the most recent addition to the nursery and is constructed from shipping containers.

Reflecting the heritage nature of the buildings, the shelters are reliant on natural ventilation by opening windows and doors which back onto the playground. The playground forms an outdoor classroom environment, with children able to flow freely between the playground and shelters.

The nursery playground is extensive and located between the shelters and to the south of the site. A group of tall apartment buildings shelter the playground from the A200 Creek Road. The playground also has extensive greenery including mature trees, shrubs and planting.

The school has seven boilers distributed across six boiler rooms and were considered in excellent working order. The flues exit at wall level, with a number exiting directly onto the playground area. This would increase children’s exposure to local emissions.

The classrooms large windows and doors, and given the age of the building are likely to be poorly insulated, which would result in greater heat loss, and so potentially increased run times by school boilers, and therefore greater emissions. It also results in higher temperatures during warmer weather, requiring windows/doors to be opened and so greater exposure. The school noted that heating is not even between shelters.

Shelter 6 is prone to overheating in winter (due to the heating system) and also very hot in summer. Shelter 4 is known to be very cold in winter as the heating system is not effective. It is also very hot in summer.

The school noted that the windows and doors of all the shelters need replacing and upgrading, which is prohibitively expensive in order to meet the heritage requirements.

Summary of AFS and control rooms and trial conditions:

- 2 floor-standing AFS deployed in the Shelter 4 classroom - mid-sized classroom (approximately 88 m^2). Naturally ventilated with open windows. External doors in regular use. Approximately 15 children in the classroom, and 2-3 staff.
- Unit operation settings – continuous operation (24 hours), fan speed setting 2
- The control room was Shelter 3 classroom, which is comparable with Shelter 4 classroom.

The baseline air quality monitoring results for Rachel McMillan were as follows:

- NO2 concentrations were found to be highest at the roadside (36.55µg/m^3), with local road traffic emissions contributing significantly to roadside concentrations.
- NO2 concentrations fall to 33.11µg/m^3 in the playground, which is partially screened from traffic by fencing and some trees and shrubs. Concentrations at the nursery entrance are of a slightly higher level (35.41µg/m^3) to the playground.
- Inside the nursery, concentrations fall by 7-18µg/m3 compared to external concentrations.
- The NO2 I/O ratio was 0.60 at Rachel McMillan Nursery School, indicating that uncontrolled infiltration rates are at the lower end of the spectrum, and so offers a reasonable level of protection to its occupants relative a more airtight building.
- Volatile Organic Compounds (VOCs) were found to be 94.6µg/m3. The majority of VOCs detected were chemical species which could be identified as being likely to be indoor pollutants, and included fragrances, perfumes and alcohols, likely to be products derived from use of cleaning materials and solvents.
- Formaldehyde were found to be 4.04 µg/m3.

Nell Gwynn

Nell Gwynn Nursery is located in South London within the London Borough of Southwark. At the time of the audit the nursery had 169 children, of which 21 are full time (30 hrs per week), and the remainder (158) are part time (15hrs per week).

The nursery is housed in a brick built building constructed in 1911, and was formerly a school, and prior to that the site was a brewery. The majority of the building is single storey with high pitched roofs, though there are mezzanine floors in a corner of each classroom, and within the main hall.

The two 2-year olds classrooms are located at the rear of the building, on the southern side of the building, screened from Meeting House Lane. The classrooms open out onto the 2-year old's playground, and the children typically free-flow between the classroom and the playground throughout the day, with exception of lunch break and an initial settling in period. The external doors are left open, with a butchers curtain fitted to retain the heat.

The 2-year-old playground is a small and relatively enclosed area, with the high brick wall of the police station car park forming the southern boundary.

The four 3-4-year-old classrooms are located at the rear of the nursery, away from Meeting House Lane and the construction site. The classrooms each have large windows and double height ceilings, with external doors leading to the rear playground. The children typically free-flow between the classroom and the playground throughout the day. The playground backs onto residential properties, and to the police station on the southern boundary, with is some limited vegetation.

The classrooms are each accessed off a large central hall, which is used extensively by the children in addition to their classrooms.

The nurseries plant room is located on the southern side of the site, and contain two small domestic type boilers. The boilers were considered to be in reasonable working order, however both vent their exhausts from the wall directly into the adjacent playground used by the 2-year olds, which can be problematic, though the density of the exhausts mean they will generally rise.

The nursery is reliant on natural ventilation through opening doors and windows, with a number of the rooms reported to get excessively hot, particularly the administrative staff and management teams offices on the first floor. The classrooms feature high ceilings and large windows, and given the age of the building are likely to be poorly insulated, which would result in greater heat loss, and so potentially increased run times by the nurseries boilers, and therefore greater emissions. It also results in higher temperatures during warmer weather, requiring windows/doors to be opened and so greater exposure. The nurseries radiators were replaced in 2014 after one exploded.

As would be expected in a nursery, paints and glue sticks were used widely by the children throughout the classrooms, and consequently the odour was noticeable around these areas. When not in use they are stored in the Long Store, which is not accessible to the children.

There was not a strong odour of cleaning products in the building, and when not in use they are stored away from the classrooms behind closed doors in the laundry room, which is not accessible to the children.

The classroom floors comprised lino or vinyl, with areas of carpet tiles. There is wood flooring in the main hall. The rooms are furnished with items made from a variety of materials including wood (some of which are likely to be MDF), plastic, metal, wicker, as well as some soft furnishings. The nursery building contained only a limited number of green plants.

Summary of AFS and control rooms and trial conditions:

- 2 wall-mounted AFS deployed in the 3-4-year-old classrooms are located at the rear of the nursery. Mid-sized classroom with double-height ceilings and mezzanine area (approximately 70 m^2). Naturally ventilated with open windows. External doors in regular use. Approximately 12-15 children in the classroom, and 2-3 staff.
- Unit operation settings – continuous operation (24 hours).
- The control room was a second comparable 3-4 year olds classroom.

The baseline air quality monitoring results for Nell Gwynn were as follows:

- NO2 concentrations were found to be highest at the roadside (47.20µg/m^3), with local road traffic emissions contributing significantly to roadside concentrations. In each month, the measured NO2 concentrations exceeded the annual mean NO2 national Air Quality Objective (AQO) of 40µg/m^3.
- NO2 concentrations fall to 32.62µg/m^3 in the playground, which is partially screened from traffic by fencing and some trees and shrubs. Concentrations at the nursery entrance, which is not screened from the road, are slightly higher than in the playground (35.05µg/m^3).
- Inside the nursery, concentrations fall to 24.40µg/m3 at the nursery entrance and 26.52µg/m3 in the classroom.
- The NO2 I/O ratio was 0.70 at Nell Gwynn Nursery School, indicating that uncontrolled infiltration rates are at the higher end of the spectrum, and so offer less protection to its occupants than a more airtight building.
- Volatile Organic Compounds (VOCs) were found to be 190.23 µg/m3. The majority of VOC chemical species identified were recognised as being likely to be indoor pollutants, and included

fragrances, perfumes and alcohols, likely to be products derived from use of cleaning materials and solvents.

- Formaldehyde were found to be 13.64 µg/m3.

Pembury House

Pembury Nursery is situated in north east London close to White Hart Lane and Tottenham football club in the London Borough of Haringey. At the time of the audit the nursery had 175 children.

The nursery has two sites. The main site and the purpose of this audit is situated on Lansdowne Road where the main entrance is located. The second site is located a ten-minute walk south in to the residential streets and located in Hartington Park.

The nursery is a single storey building, built in the 1970s, and extensively refurbished in the 1990s.

The majority of the building is screened from Lansdowne Road by the tyre business building with the entrance of the nursery protruding to the street at the eastern end.

The nursery is reliant on natural ventilation through opening doors and windows, with a number of the rooms reported to get excessively hot. The classrooms feature high ceilings and large windows, and given the age of the building are likely to be poorly insulated, which would result in greater heat loss, and so potentially increased run times by the nurseries boilers, and therefore greater emissions. It also results in higher temperatures during warmer weather, requiring windows/doors to be opened and so greater exposure.

The main class room is positioned at the southern end of the site, away from the entrance and Lansdowne Road, and faces a playground garden. The main classroom has a vaulted ceiling that falls from the centre of the building at a height of approximately three metres to the southern wall and playground garden. Two external doors are left open and PVC free flow curtains (butchers curtains) are used to retain heat. The nursey has also a few enclosed class rooms used in the morning and occasional events.

Children free-flow between the classroom and playground garden to the rear of the site. The playground wraps around to the western side where there is a gap in the buildings to Rheola Close as described above. Low rise flats bound the southern boundary. The garden has been greened and contains a number of mature trees.

The nursery is heated by a gas central heating system. The boiler room is situated at the ‘back’ of the building closest to the tyre business and the boiler flues exhaust above the roof height of the building. The boilers and control system are modern, but the auditor was informed that the building has hot and cold spots, and in summer overheating can be a problem. Standalone circulating fans are used during hot periods to maintain an air flow.

The nursery actively monitors its energy use. The building suffers from condensation and damp, and books can go mouldy. At the time of the audit one of the roof lights was leaking.

The nursery reported solvents from the tyre business can on occasion be smelt in the nursery and grounds. It was reported that the dust in the summer time was obtrusive. The head reported that their asthma had got worse since working at the nursery. The incidences of asthma amongst the children and staff is also relatively high.

The school has laminate flooring throughout. Furniture is a mixture of engineered wood and solid wood. Cleaning products are kept in a locked cupboard off the children’s toilets.

As would be expected in a nursery, paints and glue sticks were used widely by the children throughout the classrooms, and consequently the odour was noticeable around these areas. When not in use they are stored in a store room, which is not accessible to the children. There are no plants within the building as it lacks natural light.

Summary of AFS and control rooms and trial conditions:

- 1 floor-standing AFS deployed in the Creche/ Family Room - a small room (approximately 40 m^2). Naturally ventilated with open windows and a door. The room was used by parent /toddler and clinic groups with varying numbers of children and staff. It is also used for childrens events in the evenings.
- Unit operation settings – continuous operation (24 hours)
- The control room was a classroom, which is comparable with the Family Room.

The baseline air quality monitoring results for Pembury House were as follows:

- NO2 concentrations were found to be highest at the roadside (63.774µg/m^3), with local road traffic emissions contributing significantly to roadside concentrations. In each month, the measured NO2 concentrations exceeded the annual mean NO2 national Air Quality Objective (AQO) of 40µg/m^3.
- NO2 concentrations fall to 37.67µg/m^3 in the playground, which is partially screened from traffic by fencing and some trees and shrubs. Concentrations at the nursery entrance are of a higher level (40.66µg/m^3) to the playground.
- Inside the nursery, concentrations fall by 15-42µg/m3 compared to external concentrations.
- The NO2 I/O ratio was 0.53 at Pembury House Nursery School, indicating that uncontrolled infiltration rates are at the lower end of the spectrum, and so offer reasonable protection to its occupants.
- Volatile Organic Compounds (VOCs) were found to be 124.1 µg/m3. The majority of VOC chemical species were identified as being likely to be indoor pollutants, and included fragrances, perfumes and alcohols, likely to be products derived from use of cleaning materials and solvents.
- Formaldehyde were found to be 8.75 µg/m3.

Thomas Coram

Thomas Coram Centre is in Central-North London and sits within the Borough of Camden. At the time of the audit the nursery had 125 children. It also caters for 32 full-time equivalent toddlers, provided as two groups of about 39 children. The nursery has over 30 members of staff.

The nursery is housed in a modern brick built building which is 21 years' old. The building is double-storey with the nursery on the ground floor, and the first level for other agencies within the Coram charity. The nursery is essentially split into two wings which are classroom areas, connected by the administration, office and staff area in the middle.

The classrooms are split into two wings with the children split between the two. Both classrooms contain children from 2 to 5-years old and are similar in structure, layout and design.

Each wing has direct external access to a playground. The children typically free-flow between the classroom and the playground throughout the day, with exception of lunch break and an initial settling in period. Some, but not all the external doors are left open, with a butcher's curtain fitted to retain the heat.

The eastern classrooms and playground are located closest to the adjacent construction site and most affected by resulting air emissions.

The playground is fenced with high metal mesh fencing, which has a green covering to increase screening from adjacent uses. Where the playground interfaces with the adjacent construction site, there is wooden hoarding. There are some shrubs adjacent to the perimeter fencing, but it is not continuous along the length of the fence.

The nursery is mostly reliant on natural ventilation through opening doors and windows but does include ceiling fans, with several of the rooms reported to get excessively hot, particularly the administrative staff and management teams office and conservatory.

The classrooms feature relatively low ceilings and large windows which would result in greater heat loss, and so potentially increased run times by the nurseries boilers, and therefore greater emissions. It also results in higher temperatures during warmer weather, requiring windows/doors to be opened and so greater exposure.

As would be expected in a nursery, paints and glue sticks were used widely by the children throughout the classrooms, and consequently the odour was noticeable around these areas. When not in use they are stored in cupboards, which is not accessible to the children.

There was not a strong odour of cleaning products in the building, and when not in use they are stored away from the classrooms behind closed doors and is not accessible to the children.

The classroom floors comprised a mix of lino or vinyl, carpet tiles and wood flooring. The rooms are furnished with items made from a variety of materials including wood (some of which are likely to be MDF), plastic, metal, wicker, as well as some soft furnishings. The nursery building contained only a limited number of green plants.

Summary of AFS and control rooms and trial conditions:

- 1 floor-standing AFS deployed in the Yellow classroom - mid-sized classroom (approximately 48 m^2) with low-ceilings. Naturally ventilated with open windows. External doors in regular use via an adjoining conservatory/corridor leading to the playground. Approximately 16 children in the classroom, and 4 staff.
- Unit operation settings – automatic setting, turning off and on as needed. Continuous operation (24 hours).
- The control room was Shelter 3 classroom, which is comparable with Shelter 4 classroom.
- The control room was Green classroom, which is comparable with Yellow classroom on a separate wing of the building.

The baseline air quality monitoring results for Thomas Coram were as follows:

- NO2 concentrations were found to be highest at the roadside (40.90µg/m^3), with local road traffic emissions contributing significantly to roadside concentrations.
- NO2 concentrations fall to 26.39µg/m^3 in the playground, which is partially screened from traffic by fencing and some trees and shrubs. Concentrations at the nursery entrance were a higher concentration (34.86µg/m^3) to the playground.
- Inside the nursery, concentrations fall by 11-11g/m3 compared to external concentrations.
- The NO2 I/O ratio was 0.70 at Thomas Coram Centre, indicating that uncontrolled infiltration rates are at the higher end of the spectrum, and so the building offers less protection to its occupants than a more airtight building.

- Volatile Organic Compounds (VOCs) were found to be 145.9 µg/m3. The majority of VOC chemical species detected were identified as being likely to be indoor pollutants, and included fragrances, perfumes and alcohols, likely to be products derived from use of cleaning materials and solvents.
- Formaldehyde were found to be 13.66 µg/m3.

Dorothy Gardner

The Dorothy Gardner Nursery is located in the north west of the City of Westminster and can accommodate up to 87 children. At the time of the audit the nursery could accommodate up to 87 children.

The main entrance to the nursery is via Shirland Road. The nursery has one playground, that is located directly adjacent to the roundabout with Shirland Road and Fernhead Road. There is limited screening from the surrounding roads, in the form of a fence and some greenery. Staff highlighted that the children spend a large proportion of their day outdoors.

The building itself is thought to be of 1970s construction and is split over two storeys. It is considered to be relatively well insulated but is reliant on natural ventilation meaning windows and doors are opened when it is too warm.

The main classroom used by children is located closest to the Fernhead Road and Shirland Road roundabout, which has large windows and high ceilings, with external doors leading to the playground. Children are able to free-flow between the classroom and the playground throughout the day. The room is reliant on natural ventilation and it was noted from staff that the nursery often have the doors to the playground left open for access to the playground, even in the colder months, which results in greater heat loss and so potentially results in increased run times by nursery boilers and therefore emissions. The nursery has also a few enclosed small class rooms often used by small children.

The boiler is located in a single plant room and was considered by the nursery caretaker to be in 'good' condition. It is 14 years and the flues exit onto the roof, away from areas used by children. The boiler would need to be maintained to extend its life span as it already has more than 10 years of service.

There was not a strong odour of cleaning products in the building, and when not in use they are stored in the store room, away from the classrooms behind closed doors, which is not accessible to the children.

As would be expected in a nursery, paints and glue sticks were used widely by the children throughout the classrooms, and consequently the odour was at times noticeable around these areas. When not in use they are stored in the store room, which is not accessible to the children.

Summary of AFS and control rooms and trial conditions:

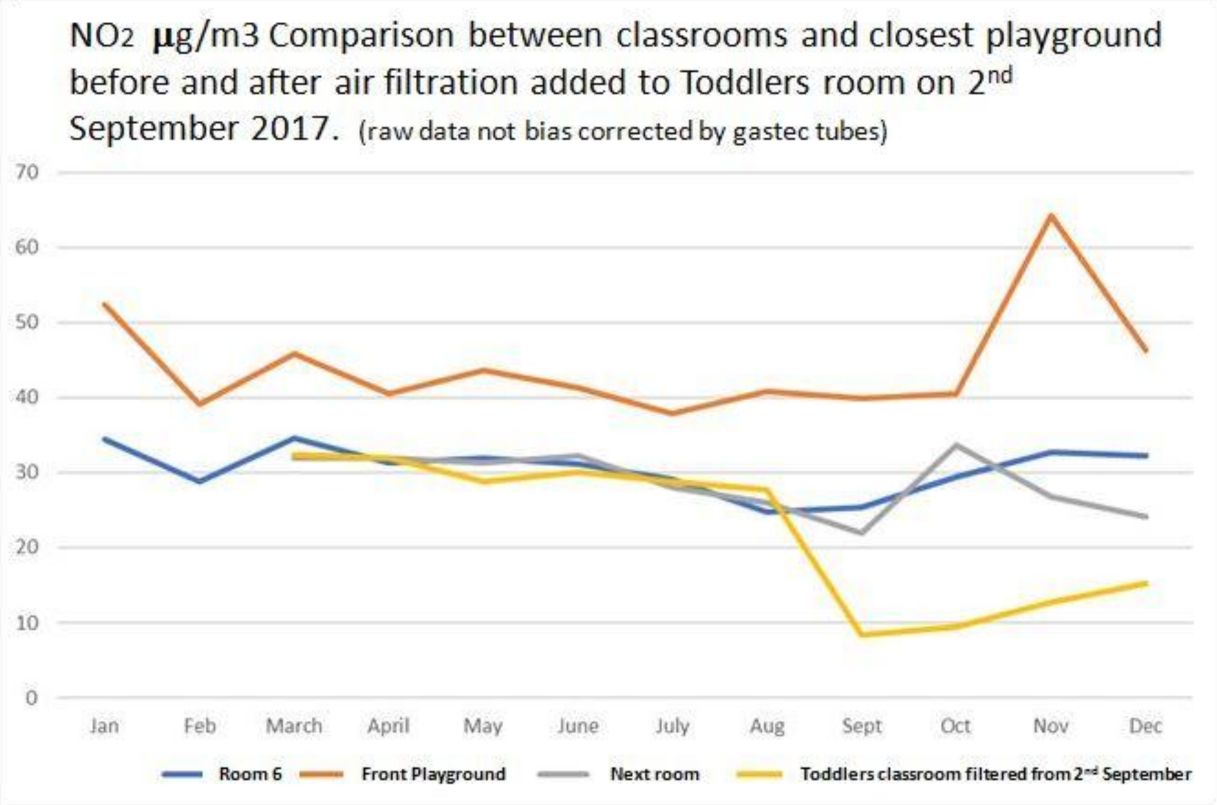
- 1 wall- mounted AFS deployed in a down-stairs small-sized classroom (approximately 25 m^2) with low-ceilings. Naturally ventilated with open windows. Approximately 10 children in the classroom, and 3 staff.
- Unit operation settings – automatic setting, turning off and on as needed. Continuous operation (24 hours).
- The control room was a second comparable classroom.

The baseline air quality monitoring results for Thomas Coram were as follows:

- NO_2 concentrations were found to be highest at the roadside (37.52µg/m³), with local road traffic emissions contributing significantly to roadside concentrations. In each month, the measured NO_2 concentrations slightly exceeded the annual mean NO_2 national Air Quality Objective (AQO) of 40µg/m³.
- NO_2 concentrations were found to be slightly lower (34.83 µg/m³) in the playground, which is partially screened from traffic by fencing and some trees and shrubs. Concentrations at the nursery entrance are of a lower level (32.21 µg/m³) to the playground.
- Inside the nursery, concentrations fall by 9-17µg/m3 compared to external concentrations.
- The NO_2 I/O ratio was 0.64 at Dorothy Gardner Nursery School, indicating that uncontrolled infiltration rates are at the intermediate end of the spectrum, with the building offering a moderate level of protection to its occupants.
- Volatile Organic Compounds (VOCs) were found to be 73.5 µg/m3. The majority of VOC chemical species were identified as being likely to be indoor pollutants, and included fragrances, perfumes and alcohols, likely to be products derived from use of cleaning materials and solvents.
- Formaldehyde were found to be 10.16 µg/m3.

Appendix B

CAMFIL - TECHNICAL SPECIFICATIONS, TEST RESULTS AND SUPPORTING MATERIALS



CC Air purifier unit

Two **Camfil** CC concealed air purifiers were installed in the toddlers classroom area on 2nd September 2017. This classroom has adjoining doors to the next class room and to the Front playground. There was an immediate reduction in NO2 levels with an average reduction compared with outdoor levels of about 75% and 65% between rooms. There was some interaction between the two adjoining classrooms as the Room6 which adjoins the Next room on the other side was much less influenced. The connecting door between Toddlers and Next room was often propped open. These curves demonstrate a real life working school environment. The **Camfil** CC units remove toxic PM1 fine combustion particles to a high efficiency with HEPA filtration as well as the nitrogen dioxide found in traffic air pollution.

School study showing measured **reduction in NO2 of about 75%** to outside over many months. Unit shown mounted in false ceiling void. Classroom has doors directly opening into playground and adjoining room.

REF : London School Study 2017 - Showing an effective air cleaning solution removing NO2 and PM1 toxic particles to a high level of efficiency

Office test - City S air purifier unit

Over 25 Minutes

Readings taken by a TSI Aerotrak 9306 Particle counter

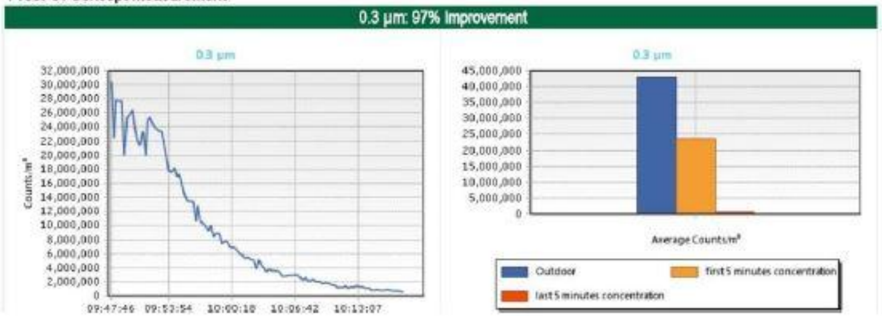
Range 0.3 to 5 microns

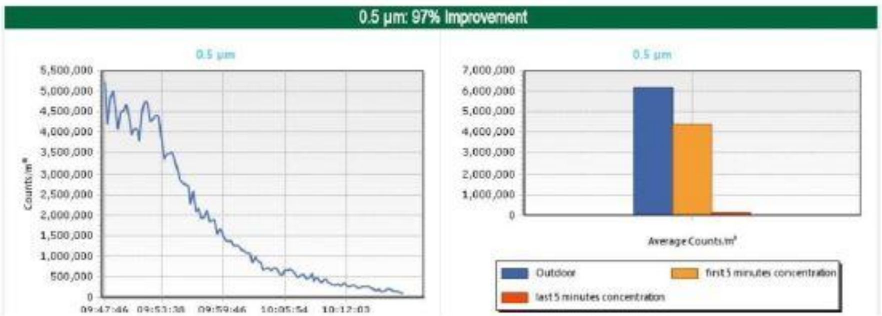
97% - 98% Particle (0.3dia.) Reduction

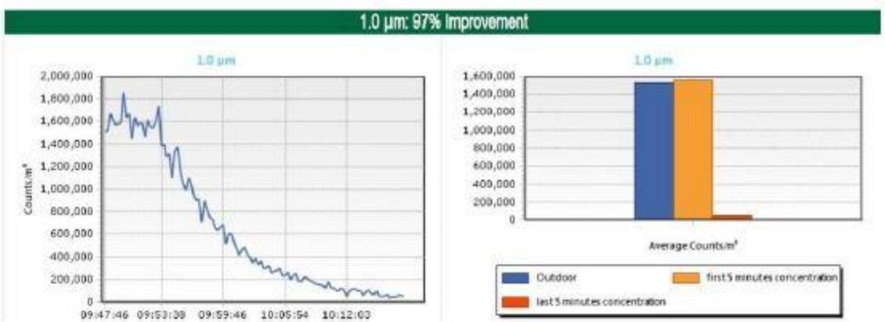
City M

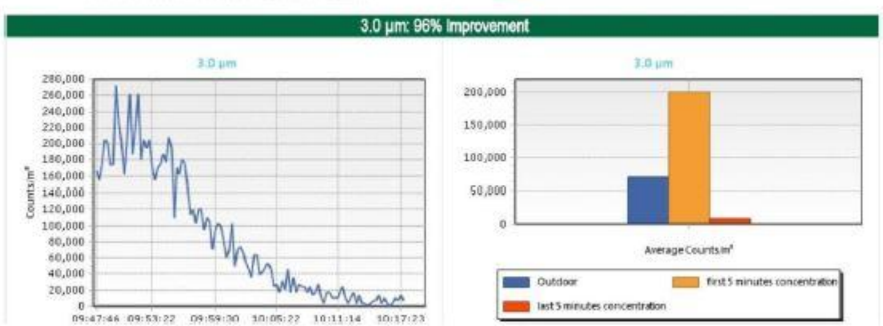
City S

Proof Of Concept Measurement









Molecular filter test report

ISO 10121-2 TEST REPORT			
Project number	CamCarb CG 600	WR number	WR2964
Report no.	MFTR17033	Date received	2017-09-20
Date tested	2017-12-14	Date report	18/12/2017

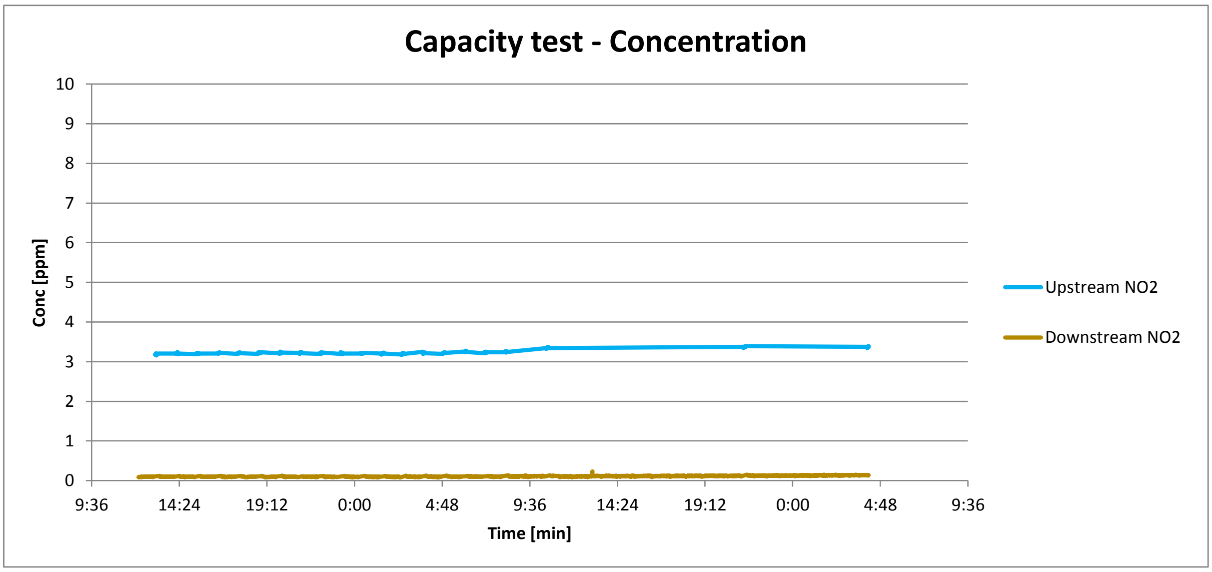
TEST SUPPLIER:			
Test organization	Camfil AB	Supervisor	G Nilsson
Operator	C Molin		

TEST CUSTOMER:			
name of customer	CamCarb CG 600		

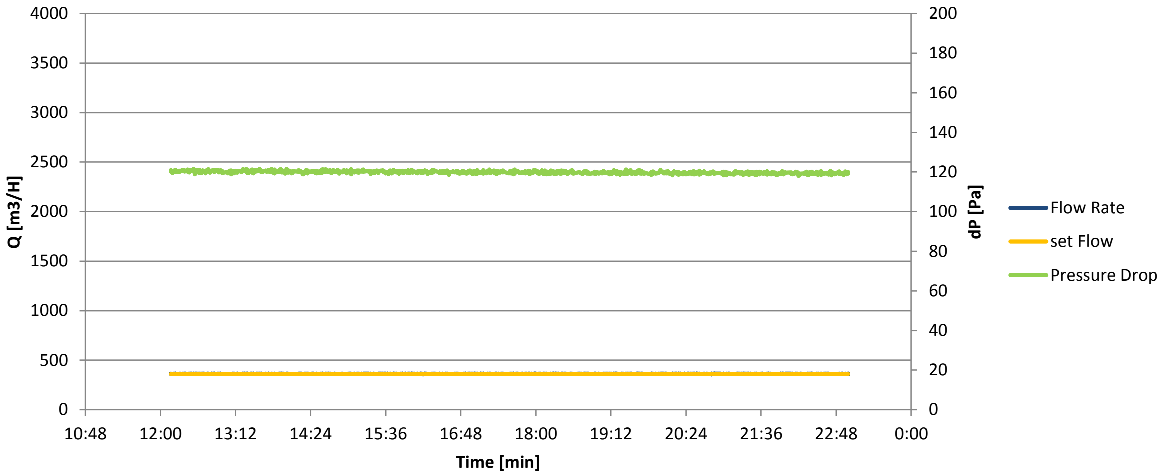
TESTED DEVICE:			
Manufacturer	Camfil Germany	Art no	94020078
Product Model / Name	CamCarb CG 600	Type	Molecular
Gas Type	NO2/NO	Dimensions [mm]	Minicarb 600
Rated flow [m3/h]	362	GPACD mass [g]	
Pressure drop [Pa]	120	Media Type	CEX003A6
Article Number	Molecular Carbon		Molecular Carbon

TESTING CONDITIONS:							
Air flow [m3/h]		362		initial eff. Conc [ppb]		86	
Face vel. [m/s]				Challenge conc. [ppb]		3000	
Test gas		NO2/NO		Temp°C	23	RH [%]	50
Analyser		Thermo 17C		Model	CamCarb CG 600		
tRE [s]		tDE [s]		tRC [s]		tDC [s]	
Comments	The NO-logging started 14:00 15 december. 9 cylinders was tested.						

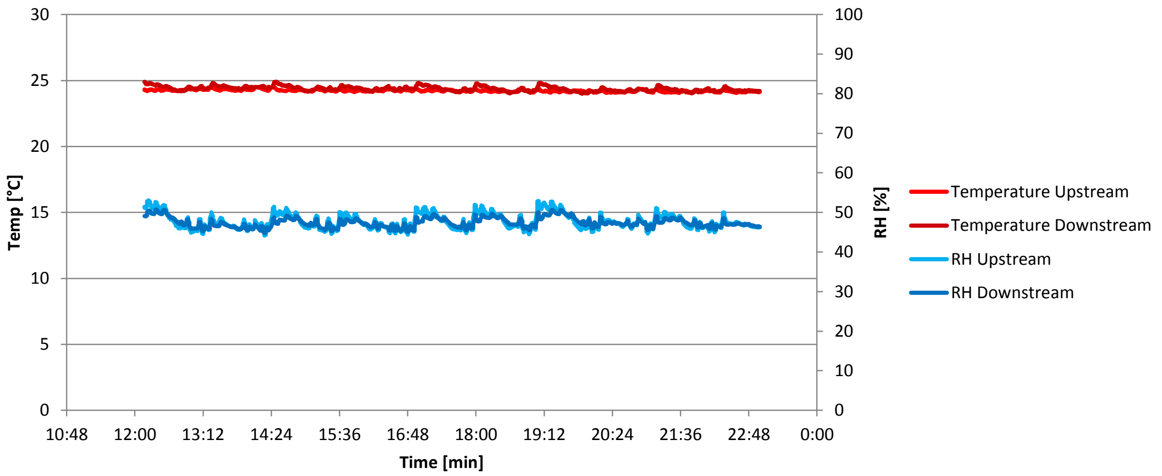
Ei [%]				Initial Ec [%]	97,3
ms, capacity [g]		efficiency 95 %	-	efficiency 90 %	-
		efficiency 70%	-	efficiency 50 %	-
		efficiency 30%	-	Total	>83.26 g
mr, retentivity				Delta P [pa]	120



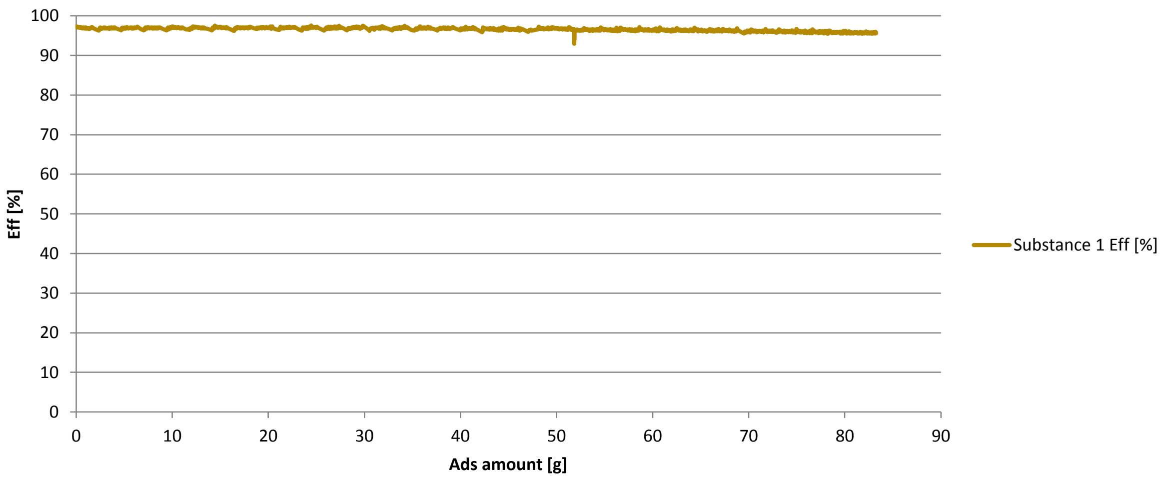
Capacity test - flow and pressure drop



Capacity test - relative humidity and temperature

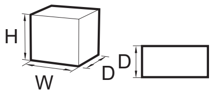


Capacity test - Efficiency vs ads



Capacity test - efficiency vs time

Air Cleaner CC 400 Concealed



Advantages

- Healthier employees
- Less cleaning
- Lower energy costs
- Reduced environmental impact
- Clean products, fewer operational disruptions
- Easy to adapt ducts and diffusors
- Less odour

Applications: Air purifier for rooms measuring up to 120 m², for example small or medium offices. Can also be used to complement larger air purifiers.
Nominal voltage range: 110..120V or 200..240V
Frequency / Hz: 50/60
Filter: F7 and H13 as standard.
Duct Connection: 2 pc Ø250mm
Capacity: 0-410 m^3/h, Air Flow controlled as standard by 6 stage controller card, or with Air Image Sensor.
Installation: Wall or ceiling (built in)
Design: Galvanized or Stainless Steel.
Air purification area: MAX 120m²

Item no.	Type	Dimensions (WxHxD) mm	Weight kg	Air volume m³/h	Initial pressure drop Pa	Noise level dBa	Power input W	Current draw Amp	Filter included in standard version *
94000080	CC 400 Concealed 230V (Galv)	1113X313X327	21,9	0-410	137		170W	1,4	XLT F7 + H13
94000090	CC 400 Concealed 230V (SS)	1113X313X327	21,9	0-410	137		170W	1,4	XLT F7 + H13
94000103	CC 400 Concealed 115V (Galv)	1113X313X327	21,9	0-410	137		170W	2,4	XLT F7 + H13
94000092	CC 400 Concealed 115V (SS)	1113X313X327	21,9	0-410	137		170W	2,4	XLT F7 + H13

Upgrades / Accessories / Exchange

Art. Nr	Description	Type	No/machine
Upgrades:			
94000117	Pre(**P**)/Molecular(**M**)/HEPA(**H**)	Filter configuration	
94000118	Pre(**P**)/HEPA(**H**)/Molecular(**M**)	Filter configuration	
94000116	Upgrade to H14	Main filter	
Accessories:			
94000015	UK plug		
Spare filter:			**No/machine**
94020023	HI-FLO-F7-287/287/370-5-25	Pre filter	1
94000119	3GPA 287x287x96-F7	Pre filter	1
94020022	E11-287x287x292	Main filter	1
94020024	H13-287x287x292	Main filter	1
94000104	H14-287X287X292	Main filter	1
94020046	CamCarb CG 600 VOC	Molecular	9
94020049	CamCarb CG 600 Formaldehyde	Molecular	9
94020052	CamCarb CG 600 Decontamination	Molecular	9
94020076	CamCarb CG 600 Smoke Remover	Molecular	9

Appendix C

IQAIR - TECHNICAL SPECIFICATIONS, TEST RESULTS AND SUPPORTING MATERIALS

Technical Specifications: *IQAir® HealthPro® 100* NE

General Specifications	
Power requirements	220-240 V, 50/60 Hz
Energy consumption *	1: 20, 2: 36, 3: 54, 4: 74, 5: 105, 6: 135 Watt; Standby: <1 Watt
Dimensions (without / with packaging)	H 61 x W 38 x D 41 cm / carton: H 74 x W 43 x D 45 cm
Weight (without / with packaging)	12 kg / 16 kg
Air delivery (incl. filters) *	1: 50, 2: 100, 3: 170, 4: 240, 5: 330, 6: 470 m^3/h
Sound pressure/power level **	L_P 1: 22, 2: 33, 3: 41, 4: 47, 5: 52, 6: 57 dB(A); L_W 1: 32, 2: 43, 3: 51, 4: 57, 5: 62, 6: 67 dB(A)
Fan motor	centrifugal, backward curved, with thermal protector, non-stop use approved
Control panel	4-key touch-pad with 16 character 2-line LCD display
Air intake	dual arches at base of unit
Air outlet	320° EvenFlow™ diffuser
Colour of main housing / locking arms	light grey / white
Housing material	non off-gassing, impact-resistant, UV-stabilized ABS
Performance	
Total system efficiency (certified)	≥ 99.97% for particles ≥ 0.3 µm (individually tested at highest fan speed)
Air delivery (certified)	yes (individually tested with all filters fitted)
Leak tested	yes
EN1822 classification	HEPA class H13 (MPPS efficiency: ≥ 99.95% @ 0.22 µm at airflow rate ≤ 190 m^3/h) HEPA class H12 (MPPS efficiency: ≥ 99.50% @ 0.16 µm at airflow rate ≤ 475 m^3/h)
Filter Configuration	
Pre-filter	***PreMax™ Filter F8 (S)*** Purpose: control of coarse and fine particulate matter; protection of subsequent filters Media: non-woven glass microfiber, mini-pleated for high-capacity Efficiency: ≥ 55% at ≥ 0.3 µm (class F8) Surface area: 2.8 m^2
HEPA-filter	***HyperHEPA® Filter H12/13 (L)*** Purpose: control of fine & ultra-fine particulate matter Media: non-woven glass microfiber, hospital-grade HyperHEPA® filter Efficiency: ≥ 99.97% at ≥ 0.3 µm (class H12/13) Surface area: 5.0 m^2
Features	
Display languages	4 user-selectable languages: English, French, German, Italian (or Spanish)
Fan speed settings	6
Intelligent filter life monitor	yes (monitors actual usage of each individual filter)
Filter life status LEDs	2
Advanced timer	yes (allows programming of operating hours and weekdays)
Advanced fan speed selection	yes (allows programming of different fan speeds for 2 different time periods)
Adjustable filter load indices	2 (large dust and fine dust)
Supplied accessories	remote control (incl. battery), power cord with plug, casters, certificate of performance
Optional accessories	***VMF*** wall-mount bracket, ***PF40*** coarse dust pre-filter, ***InFlow, VM InFlow*** & ***OutFlow*** duct connections, ***FlexVac*** & ***VM FlexVac*** mobile & wall-mounted source capture kits.
Electrical safety certification	IEC/IECEE (CB-Scheme), CE, SEV, KTL, GOST-R

* per fan speed measured at 230V, 50Hz; tolerance ± 10% (± 10 m^3/h); ** tolerance: ± 3 dB(A); All technical specifications are subject to change without prior notice.

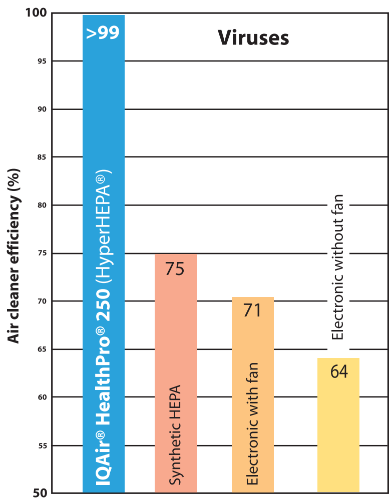
Independent laboratory test confirms: IQAir's HyperHEPA® is best technology

The accredited test *laboratory Interbasic Resources, Inc.* purchased a number of room air cleaners on the open market and tested them for their filtration efficiency. Only the *IQAir HealthPro® 250* was able to trap over 99% of virtually all types of pollution particles. Since the *Allergen 100* and *HealthPro 150* models feature identical particle filters to the HealthPro 250, the same results can also be expected of these models.

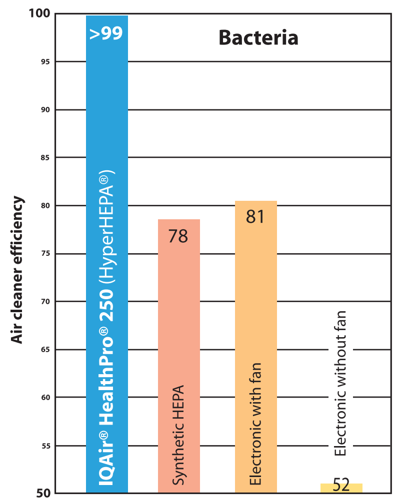
The 4 air cleaners tested are among the best rated air purifiers of their respective air cleaning technologies:

- IQAir HealthPro® 250
- Synthetic HEPA air cleaner
- Fan-powered electronic air cleaner
- Fanless electronic air cleaner

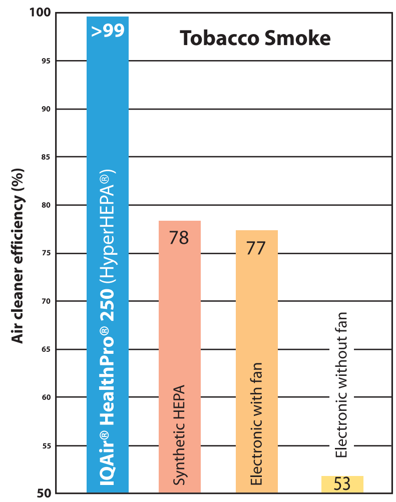
The below graphs show the results of independent laboratory tests conducted by *Interbasic Resources, Inc.*, Michigan, USA. All air cleaners were tested in new condition at high (fan speed) setting.



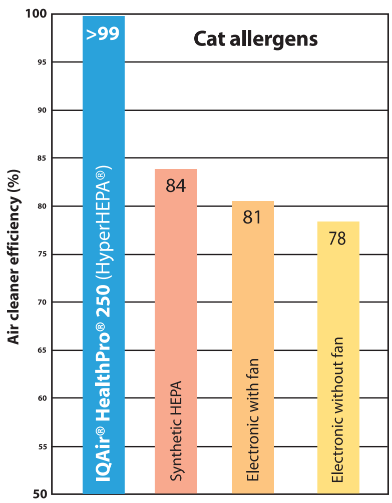
Efficiency was determined for virus size particles (0.01-0.02 microns)



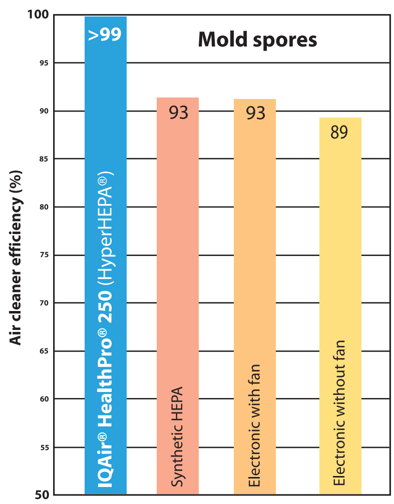
Efficiency was determined for bacteria size particles (0.1-0.3 micron)



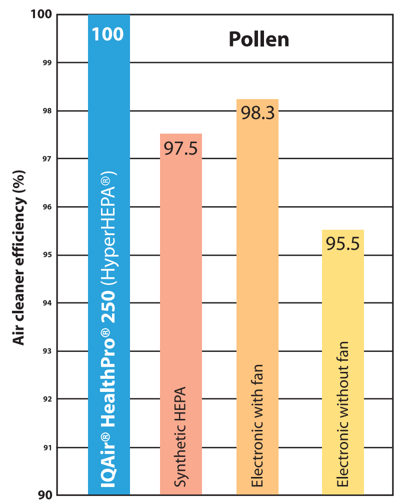
Efficiency was determined for tobacco smoke size particles (0.05-0.5 microns)



Efficiency was determined for cat allergen size particles (0.3-3.0 microns)



Efficiency was determined for mold spore size particles (3.0-5.0 microns)



Efficiency was determined for pollen size particles (>5 microns)

INCEN AG

Blumenfeldstr. 15 • CH-9403 Goldach • Switzerland • Tel.: +41 71 844 0844 • Fax: +41 71 844 0845 • e-mail: info@incen.com • www.iqair.com

The main advantages of a high efficiency air cleaner

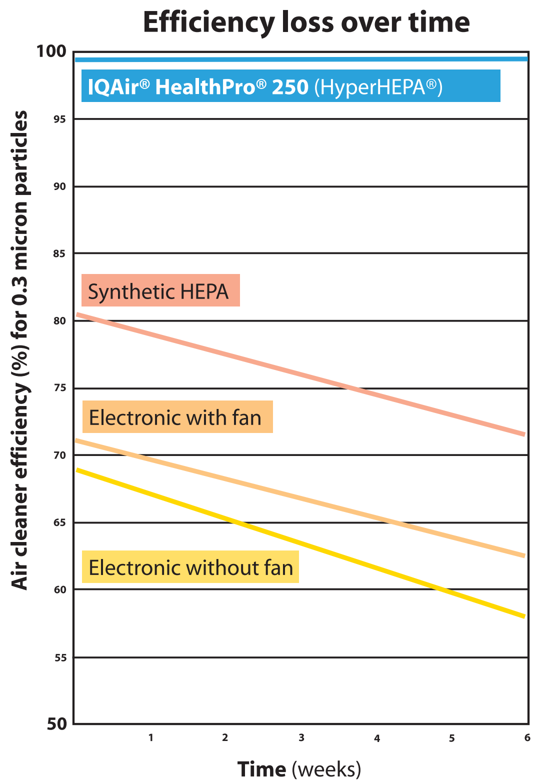
While high efficiency is not the only performance parameter of an air cleaner, it is one of the most important features. A high efficiency air cleaner ensures that:

1. Users in proximity to the air cleaner breathe the cleanest possible air.
2. Less air circulation (air delivery) is needed to clean the air in a room. This means that the air cleaner can be set to a lower speed than less efficient air cleaners, resulting in less noise and less air drafts.
3. Trapped air pollutants remain in the filter and are not released back into the room.

IQAir's efficiency never decreases - it actually increases with usage

The independent test results on the previous page, are for air cleaners in new condition. Further testing has shown that the efficiency of all the tested air cleaners, except the IQAir system, drastically decreases with usage. Over time these air cleaners trap less and less pollution particles and may actually start to release trapped particles.

Electrostatic air cleaners need to be cleaned constantly to counteract this drastic loss of efficiency. IQAir's efficiency never decreases, even without filter maintenance*. Trapped particles are never released back into the environment. That is one of the main reasons why IQAir systems with HyperHEPA technology are used for airborne infection control in critical hospital environments across the world.



* Filter maintenance is not required to retain filtration efficiency, but to retain high air delivery rates.

Commercial Air Filtration by AllergyCosmos

IQAir®

Air Filtration for a London-based Primary School

Pictured left: An IQAir air purification system fitted in a lower school classroom in Notting Hill Preparatory School.

Installation Date

November 2017

Notting Hill Preparatory School is based in Ladbroke Grove, Central London. It has over 300 pupils and comprises of two separate buildings (representing lower and upper school). Classrooms in the lower school are medium size rooms and do not contain a ventilation system with the ability to provide a sufficient standard of air quality. Maintaining adequate levels of air quality is an increasing concern for schools in London, due to high levels of pollution, which have a severe short-term and long-term health impact on children.

What was the school's issue?

What was the cause?

Due to the schools location in central London, they are exposed at times to high levels of general air pollution, which includes traffic pollution. Outside air pollution seeps into the school and is inhaled by the staff and children. This means the people inside the school are vulnerable to poor air quality and this is damaging to their health.

What did we do about it?

What was done?

Notting Hill Preparatory School asked us to consult them on how to create and maintain healthy air quality in their classrooms. After an on-site assessment and consideration of different options, the IQAir CleanZone SLS high performance air purifiers were installed in several classrooms. AirVisual air quality monitors were also setup in the classrooms to monitor the air quality on an ongoing basis.

Why these products?

The IQAir CleanZone SLS (pictured left) is the most efficient, undisruptive and cost effective way to control airborne contamination in a large classroom environment. Ultra-quiet performance, a high airflow rate and high efficiency HEPA filtration, enables the unit to provide the best possible results.

The AirVisual Node (pictured right) is a laser air quality monitor, which uses a high accuracy PM2.5 laser sensor to measure: particulate, CO_2, humidity and temperature. It also connects to local government testing stations to provide up-to-date outdoor air pollution readings in Ladbroke Grove.

Why was it done?

Children are especially susceptible to the negative long-term and short-term effects of air pollutants on their health. With urban areas such as London suffering with especially high levels of pollution, the quality of air children breathe on a day-to-day basis is ever more important.

What are the health effects of poor air quality? The short-term health effects of being exposed to poor air quality range from: headaches, nausea, increased allergy and asthma symptoms, to an inability to concentrate. Long-term health effects can be more severe, affecting physical and mental health and development.

How long did the implementation take?

All units were installed, configured and operational in a single afternoon. No alteration to the building was required.

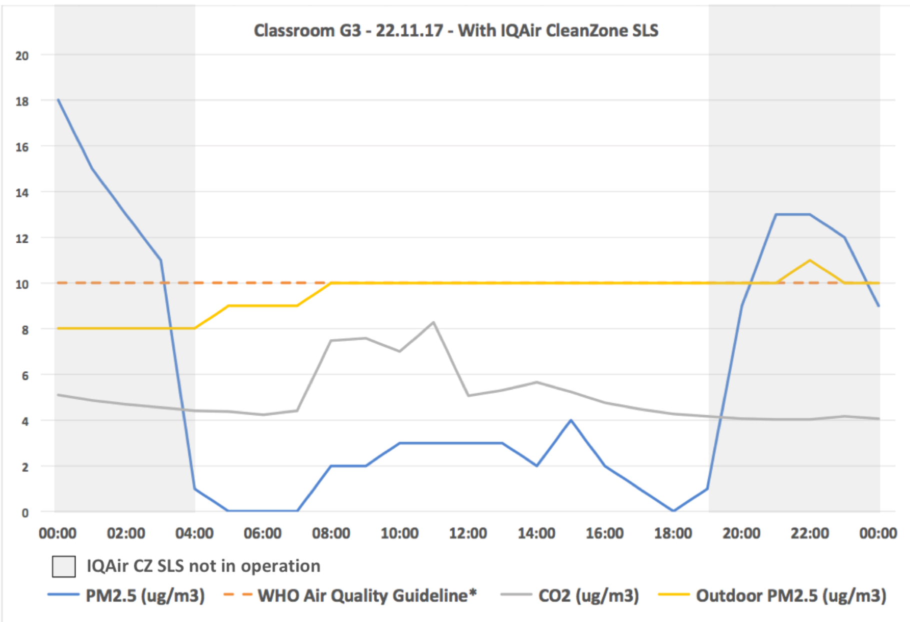
Who are we?

Schools, businesses and government institutions contact Commercial Air Filtration to find the best air quality solutions. Our team of air quality experts and consultants can advise you on monitoring and filtering the air quality in any indoor environment. We work with the best international manufacturers and can provide solutions for every concern and budget.

In addition to helping government institutes and businesses throughout the UK, our sister company, Allergy Cosmos, helps domestic customers to control airborne pollution in their home.

What was the result?

A reduction of 86% of particulate pollution in the classrooms was achieved compared to outside pollution levels. The use of the AirVisual air quality monitor also allowed the teachers to effectively monitor and control indoor pollution levels, and regulate CO2 levels throughout the day.



"The results were immediate and, importantly, are there for us to see in real time throughout the day. The units offer all-important peace of mind to parents that their children are being looked after when in our school."

Caroline Armstrong, Bursar, Notting Hill Preparatory School

For more information on how Commercial Air Filtration can help, call: 0203 176 0524

Appendix D

BLUEAIR - TECHNICAL SPECIFICATIONS, TEST RESULTS AND SUPPORTING MATERIALS

Classic 680i/605 technical specifications*

CADR (cfm)**:	Smoke	Dust	Pollen
	500	500	640

Room size		775 sq.ft. (72 m^2)
Air Changes per Hour ***		5
Airflow (Speed 1-2-3)		150-275-650 cfm
Size (HxWxD):		26 x 20 x 13 in. (660 x 500 x 340 mm)
Product weight:		35 lbs (16 kg)
Energy consumption (Speed 1-2-3)**		15-65-105 W
Sound pressure levels (Speed 1-2-3)		33-44-62 dB(A)
Filter replacement indicator		Yes
Speed control options	680i 605	1-2-3, non-touch, smartphone (Automode) 1-2-3, non-touch, smartphone
Air quality sensors	680i 605	Built-in sensors for VOC, PM2.5, temperature and humidity No sensors - optional use with Blueair Aware
		The entire unit can be recycled.

External network issues affecting the product performance are beyond the control of Blueair. Please contact your Internet service provider for assistance.

* Specifications based on U.S. models (120 VAC, 60 Hz with particle filter)

** The CADR indicates how much filtered air is delivered (airflow) by the air purifier operating at the highest setting, and how well the system removes tobacco smoke, dust and pollen pollutants from the air (efficiency). Tests are performed in accordance with ANSI/AHAM AC-1. The maximum possible CADR ratings according to this standard are: Tobacco Smoke: 450 cfm. / Dust: 400 cfm. / Pollen: 450 cfm.

*** Air changes per hour are calculated on the recommended room size, assuming 8-foot (2.4 m) ceilings. For smaller rooms, the air changes per hour will increase.

**** The available electrical power voltage and frequency affects the power consumption of the unit. The power consumption might therefore be different from the stated value.

Classic 505 technical specifications*

CADR (cfm)**:	Smoke	Dust	Pollen
	400	450	450

Room size	698 sq.ft. (65 m^2)
Air Changes per Hour* **	5
Airflow (Speed 1-2-3)	130-240-520 cfm
Size (HxWxD):	26 x 20 x 13 in. (660 x 500 x 340 mm)
Product weight:	35 lbs (16 kg)
Energy consumption (Speed 1-2-3)**	15-65-105 W
Sound pressure levels (Speed 1-2-3)	33-44-62 dB(A)
Filter replacement indicator	Yes
Speed control options	1-2-3, non-touch, smartphone (Automode)
Air quality sensors	No sensors - optional use with Blueair Aware
	The entire unit can be recycled.

External network issues affecting the product performance are beyond the control of Blueair. Please contact your Internet service provider for assistance.

* Specifications based on U.S. models (120 VAC, 60 Hz with particle filter)

** The CADR indicates how much filtered air is delivered (airflow) by the air purifier operating at the highest setting, and how well the system removes tobacco smoke, dust and pollen pollutants from the air (efficiency). Tests are performed in accordance with ANSI/AHAM AC-1. The maximum possible CADR ratings according to this standard are: Tobacco Smoke: 450 cfm. / Dust: 400 cfm. / Pollen: 450 cfm.

*** Air changes per hour are calculated on the recommended room size, assuming 8-foot (2.4 m) ceilings. For smaller rooms, the air changes per hour will increase.

**** The available electrical power voltage and frequency affects the power consumption of the unit. The power consumption might therefore be different from the stated value.

Particle, bacteria and virus removal

Removal rate for Blueair products, including particle matter, bacteria, fungus and viruses

Classic series	Bacteria [A] Staphylococcus Aureus (60 min)	Bacteria [A] Escherichia Coli (60 min)	Fungus [A] Aspergillus Niger (60 min)	Virus [B] H1N1 (60 min)	Particles ≥0.3µm (20 min)
205 PA	99,93%	99,94%	99,99%	≥99.99%	96,47%
205 SM	99,91%	99,91%	99,95%	≥99.99%	94,95%
280i PA	99,93%	99,94%	99,99%	≥99.99%	96,47%
280i SM	99,91%	99,91%	99,95%	≥99.99%	94,95%
405 PA	>99.99%	>99.99%	>99.99%	≥99.99%	99,22%
405 SM	99,99%	99,99%	>99.99%	≥99.99%	97,2%
480i PA	>99.99%	>99.99%	>99.99%	≥99.99%	99,22%
480i SM	99,99%	99,99%	>99.99%	≥99.99%	97,2%
505 PA	>99.99%	>99.99%	>99.99%	≥99.99%	100%
505 SM	>99.99%	>99.99%	>99.99%	≥99.99%	99,28%
580i PA	>99.99%	>99.99%	>99.99%	≥99.99%	100%
580i SM	>99.99%	>99.99%	>99.99%	≥99.99%	99,28%
605 PAC	>99.99%	>99.99%	>99.99%	≥99.99%	100%
605 SM	>99.99%	>99.99%	>99.99%	≥99.99%	99,28%
605 DP	>99.99%	>99.99%	>99.99%	≥99.99%	99,28%
680i PAC	>99.99%	>99.99%	>99.99%	≥99.99%	100%
680i SM	>99.99%	>99.99%	>99.99%	≥99.99%	99,28%

Pro series	PM2,5 (GB/T 18801-2008) (60 min)
Pro M SM	>99%
Pro L SM	>99%
Pro XL SM	>99%

Blue series	Bacteria [A] Escherichia Coli (60 min)	Fungus [A] Aspergillus Niger (60 min)	PM0.3 [B] (20 min)
121 [C]	-	-	99.9%
211/211+/221 [D]	99.98%	99.99%	99.9%
221 [C]	99.98%	99.99%	99.7%
411 [D]	99.96%	99.95%	87.4%

Staphylococcus aureus is a round-shaped bacterium found in the nose and respiratory tract and on the skin. It can cause infections of the skin, brain, bone, lungs and heart.

Escherichia coli are bacteria found in the environment, foods and the digestive tract of humans and animals. Foodborne and airborne exposure can cause fever, nausea, diarrhea, vomiting, gastrointestinal and urinary tract infections.

Aspergillus niger, or black mold, is a common fungus, found in the air and soil and growing on fruit and vegetables. It can cause allergies, pneumonia and, in extreme cases, weakened immune systems and lung disease.

H1N1, or swine flu, is a highly contagious virus transmitted mainly during the winter months through the air by coughing and sneezing. It can cause fever, chills, diarrhea, narcolepsy and acute respiratory infection.

SM – Blueair SmokeStop Filter
PA – Blueair Particle Filter
PAC – Blueair Carbon Sheet
DP – Blueair Dual Protection™ Filter

Pro series - According to GB/T 18801-2008 on 230V model with SmokeStop filter.

Classic and Blue series - According to GB 21551.3-2010 on 230V model - Highest speed.

[A] According to GB 21551.3-2010 on 230V model - Highest speed
[B] According to GB/T 18801-2015 on 230V model - Highest speed.
[C] With Particle and Honeycomb filter.
[D] With Particle and Carbon mesh filter.

Gaseous removal

Gaseous pollutants include organic and inorganic compounds. Organic chemicals known as Volatile organic compounds (VOCs) are emitted as gases from certain solids or liquids. Concentrations of many VOCs are consistently higher indoors than outdoors. VOCs are emitted by a long list of products and include a variety of chemicals, some of which may have short-and long-term adverse health effects. Inorganic compounds are common in gaseous pollutants and can be found indoors and outdoors. The may come from natural or man-made sources.

VOCs

Volatile organic compounds (VOCs) include thousands of different compounds. VOCs are organic chemicals found in both outdoor and indoor air. "Volatile" means that a compound is easily evaporated at normal temperatures and pressures.

VOC sources are widely used as ingredients in household products. Paints, varnishes and wax all contain organic solvents, as do many cleaning, disinfecting, cosmetic, degreasing and hobby products.

The irritating gases may play a role in a large number of illnesses, from respiratory disease to chemical sensitivity.

A quick reduction of gaseous pollutants is best achieved by SmokeStop™ or Dual Protection™, Particle and Carbon filters equipped with activated carbon.

Inorganic compounds

Inorganic compounds are any compounds that are not organic, i e does not contain hydrocarbon groups. Some inorganic compounds are carbon monoxide, carbon dioxide, Nitrogen oxide (NO_x) and Sulphur Dioxide (SO_x). NO_x is most common in air pollution. SO_x is a toxic gaseous compound that results from fossil fuel combustion. Once inhaled, it can spread deep into lung tissue, causing breathing difficulties and other health problems.

Clean Air Delivery Rate

The concept of Clean Air Delivery Rate is not limited to particles. The CADR value can also be used to indicate how well an air purifier will remove gaseous pollutants from the air. In the same way as for particles, the CADR for gaseous pollutants is determined by the unit's filtration efficiency and its airflow. The higher the CADR value, the more clean air is produced by the air purifier and the better it will be at cleaning the air in a room. CADR has also been described earlier in this document.

Testing and results

Blueair has done numerous tests in order to measure the CADR values for gaseous pollutants. In July and December 2017, Blueair tested the CADR values on the models in the Blue and Classic families. The CADR values were measured on different types of gases such as formaldehyde, VOC combinations and toluene in order to tests the filters' removal capabilities. The tests were performed on units with SmokeStop filters or particle and carbon filters according to the methods described in the Chinese standard GB/T18801-2015. CADR data for gases can be found in the CADR chapter.

Removal rate

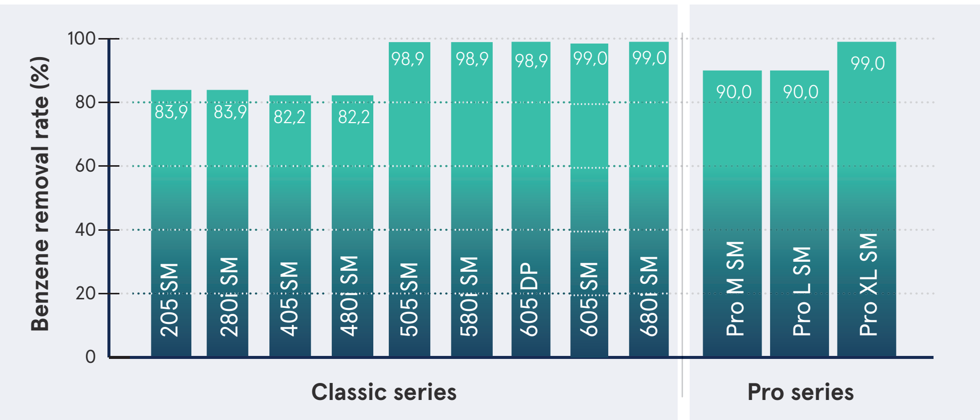
The Clean Air Delivery Rate indicates how much filtered air is delivered by the air purifier, but is also a measurement of how fast the unit is able to remove pollutants from the air. A unit with a high CADR will be able to clean the air in a room of a specific size faster than a unit with a lower CADR. The amount of pollutants that the unit removes during a specified period time is referred to as the unit's removal rate (%). The removal rate is calculated by comparing the initial amount of pollutants with the amount of pollutants remaining after the specified period of time has passed. The higher removal rate, the less gaseous pollutants remain.

Testing and results

In 2017 and 2018, Blueair conducted extensive tests on the models in the Blue and Classic families. The removal rate of a wide range of indoor and outdoor gases such as sulphur dioxide, benzene and styrene was tested. Tests were done by Guangzhou Testing Center of Industrial Microbiology, China and The Guangzhou CAS Test Technical Services Co., Ltd, China. They were done on SmokeStop filters or particle and carbon filters according to the methods described in the Chinese standard GB/T18801-2015. More information and the results from these tests can be found in the test summary later in this document.

Gas removal rate

Gas removal rate after 60 minutes for Blueair products



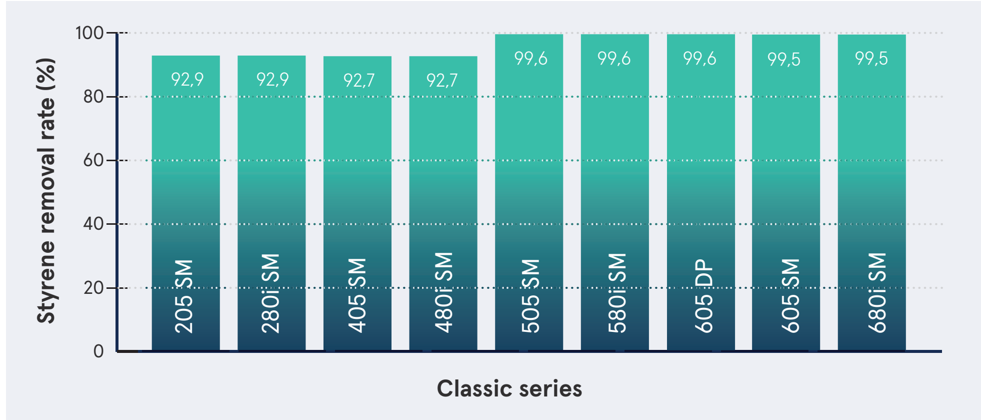
Benzene is a clear petroleum-based chemical that is widely used in the production of plastics, resins, detergents, pesticides, pharmaceuticals and synthetic fibers. It can cause dizziness, anemia, nausea, leukemia and cancer.

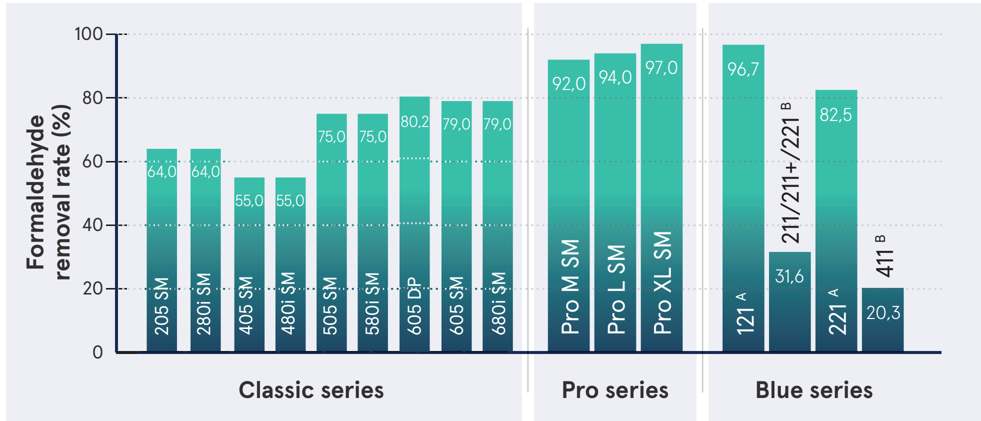
Styrene is a colorless oily liquid used in plastics, piping, insulation, fiberglass, packaging material and food containers. It can cause eye, skin and respiratory tract irritation as well as impact kidney, nervous system and gastrointestinal tract function.

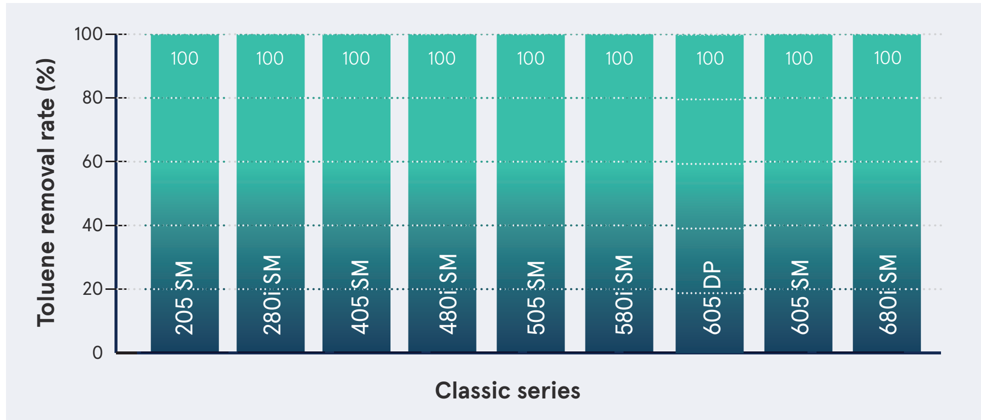
Formaldehyde is a colorless, strong-smelling chemical used in building materials, pressed-wood products, and home and personal care products. It can cause eye, nose, throat and skin irritation as well as birth defects, lung disease and cancer.

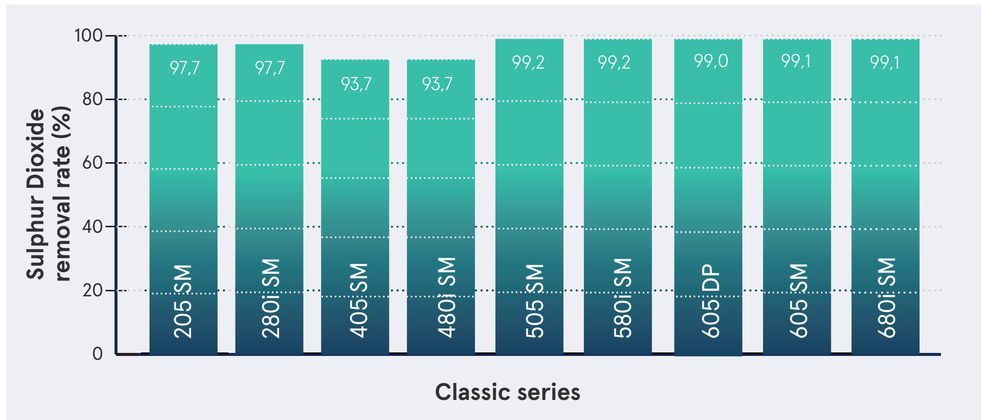
Toluene is clear, colorless liquid found in paints, solvents, disinfectants, sealants and fuels. It can cause headache, dizziness and eye, skin and respiratory tract irritation and impact the nervous and cardiovascular systems.

Sulphur dioxide is a toxic gaseous compound that results from fossil fuel combustion. Once inhaled, it can spread deep into lung tissue, it can cause breathing difficulties and other health problems.









Classic series - According to GB/T 18801-2015 with 230V model.

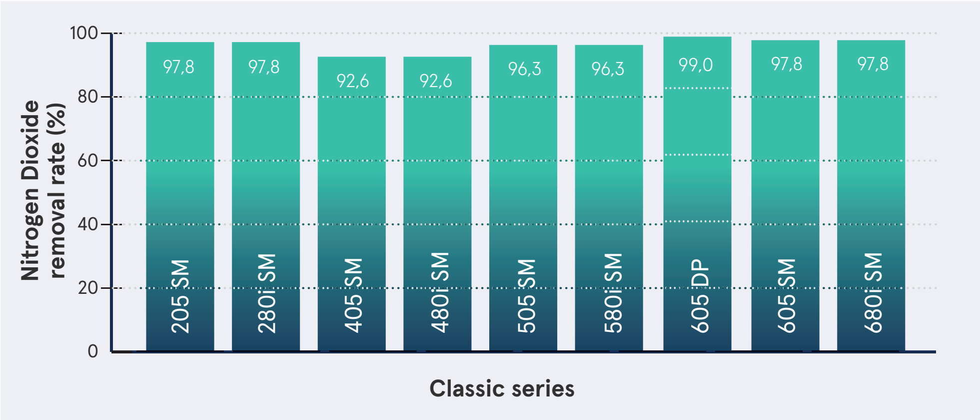
Pro series - According to GB/T 18883-2008 on 230V model with SmokeStop filter.

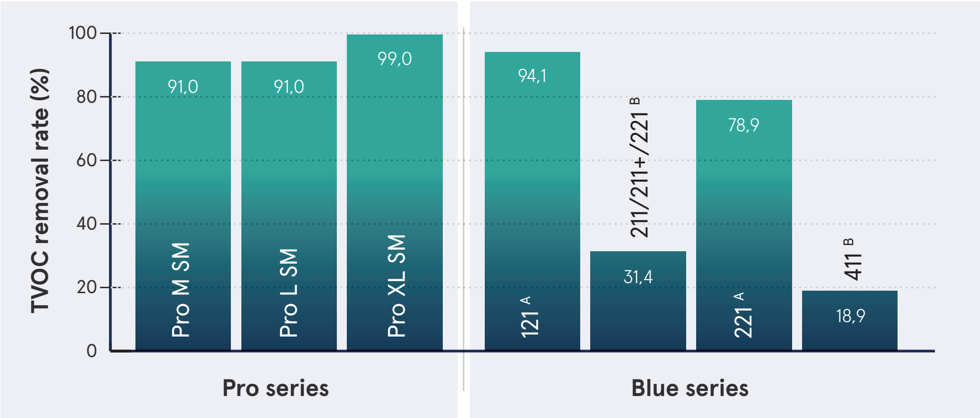
Blue series - According to GB/T 18801-2015 on 230V model - Highest speed.

SM – Blueair SmokeStop Filter
PA – Blueair Particle Filter
PAC – Blueair Carbon Sheet
DP – Blueair Dual Protection™ Filter

[A] With Particle and Honeycomb filter.

[B] With Particle and Carbon mesh filter.





Nitrogen dioxide is one of a group of gases known as nitrogen oxides (NO_x) that results from fossil fuel combustion. It can cause breathing difficulties, respiratory tract irritation and respiratory disease, such as asthma.

TVOC (Total Volatile Organic Compounds) is a measurement of the total concentration of VOC's in the air.

Classic series – According to GB/T 18801-2015 with 230V model.

Pro series – According to GB/T 18883-2008 on 230V model with SmokeStop filter.

Blue series – According to GB/T 18801-2015 on 230V model – Highest speed.

SM – Blueair SmokeStop Filter

PA – Blueair Particle Filter

PAC – Blueair Carbon Sheet

DP – Blueair Dual Protection™ Filter

A With Particle and Honeycomb filter.

B With Particle and Carbon mesh filter.

Ozone

Ozone occurs both in the Earth's upper atmosphere and at ground level. It can be good or bad, depending on where it is found. Tropospheric, or ground level ozone, is created by chemical reactions and can cause health effects even at relatively low levels.

Ground level ozone is a colorless gas formed during the reaction of nitrogen oxides from fuel combustion and volatile organic compounds in the presence of sunlight. It can cause eye irritation, coughing, wheezing, asthma and chronic obstructive pulmonary

While ozone is a molecule composed of atoms of oxygen, it should not be confused with the two-atom oxygen molecule (O_2) that we breathe to support life. Ozone, which connects three oxygen atoms (O_3) can decrease lung function and cause health effects such as chest pain, shortness of breath, throat irritation and increase the risk of respiratory health problems.

Though the HEPASilent™ technology uses electrostatic filtration to capture and remove particles from indoor air, Blueair's system should not be associated with dangerous indoor ozone that could be formed by air cleaning techniques based on only ionization, or with systems using ozone to clean the air. Since many customers are concerned with the negative effects of ozone, Blueair takes this matter seriously and is committed to making sure that our air purifiers are safe and do not add ozone to the room.

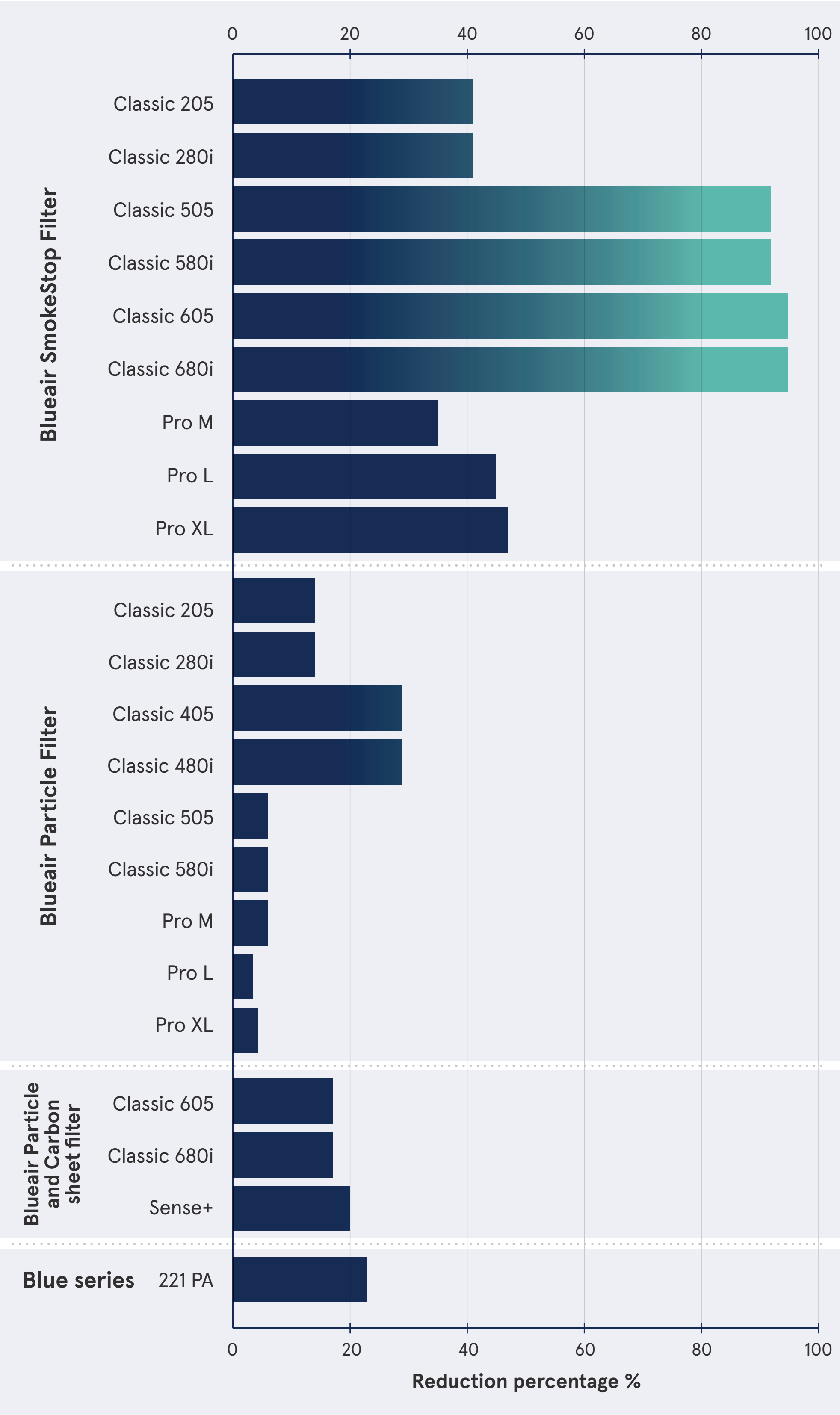
Reduction of ozone

In 2016, the ozone reducing capabilities of all Blueair models were tested. The tests were performed on units fitted with particle filters, carbon filters as well as SmokeStop filters, and concluded that ozone concentrations in the air directly after passing through Blueair's filters were lower than the ozone concentrations in the surrounding air. While these positive results were evident on units fitted with both particle filters, carbon filters and SmokeStop filters, results were most obvious with the SmokeStop filters. The design of the filter in combination with its structure of porous activated carbon most efficiently reduces ozone in indoor air.

The tests were performed at SP Technical Research Institute of Sweden in a closed chamber with the dimensions 3,0 x 3,5 x 2,5 meters. An ozone generator was used to achieve a suitable background concentration.

Ozone

Ozone reduction of Blueair products, in percent



Classic, Pro and Sense+ series tested on 230V model on lowest speed.

International ozone requirements

The international air purifier standard IEC60335-2-65:2010 requires that air purifiers do not generate excessive amounts of ozone. This is tested by running the unit in a closed chamber with the dimensions 3,0 x 3,5 x 2,5 meters for 24 hours. During the test the ozone concentration must not exceed 50ppb (parts per billion). All Blueair air purifiers are tested and comply to IEC60335-2-65:2010. The standard is adopted by many countries around the world such as Taiwan, Korea, Japan and the European Union.

To earn the ENERGY STAR the unit's ozone emission must meet UL Standard 867, the U.S. government's criteria for ozone emission, which for air purifiers is ≤50 ppb (parts per million).

ARB Certified

All Blueair air purifiers are tested and certified in accordance with the California Air Resource Board (ARB) certification program. In order to be ARB certified, the tested products are required to produce an ozone emission concentration that does not exceed 50 ppb as stated in standard UL867, section 40. This threshold is decided by the U.S. Food and Drug Administration (FDA). During the certification process the products undergo a comprehensive series of tests in a closed chamber to measure ozone emissions. The tests go on for 8-hour long test periods, at high and low speed and with and without the filter installed. All Blueair models are ARB certified showing ozone emissions far below the FDA threshold. Certified units are listed on the ARB website: https://www.arb.ca.gov/research/indoor/aircleaners/certified.htm

ARB certified products are identified by the ARB-mark printed on the product packaging with the following text:

> This air cleaner complies with the U.S. federal ozone emissions limit. ARB certified

Local requirements

All Blueair products comply to the ozone concentration requirements on the markets where they are sold. This means that the products are tested in order to make sure that they do not exceed ozone concentration levels.

European Union

In order to CE-mark air purifiers, the ozone concentration must not exceed 50ppb.

China

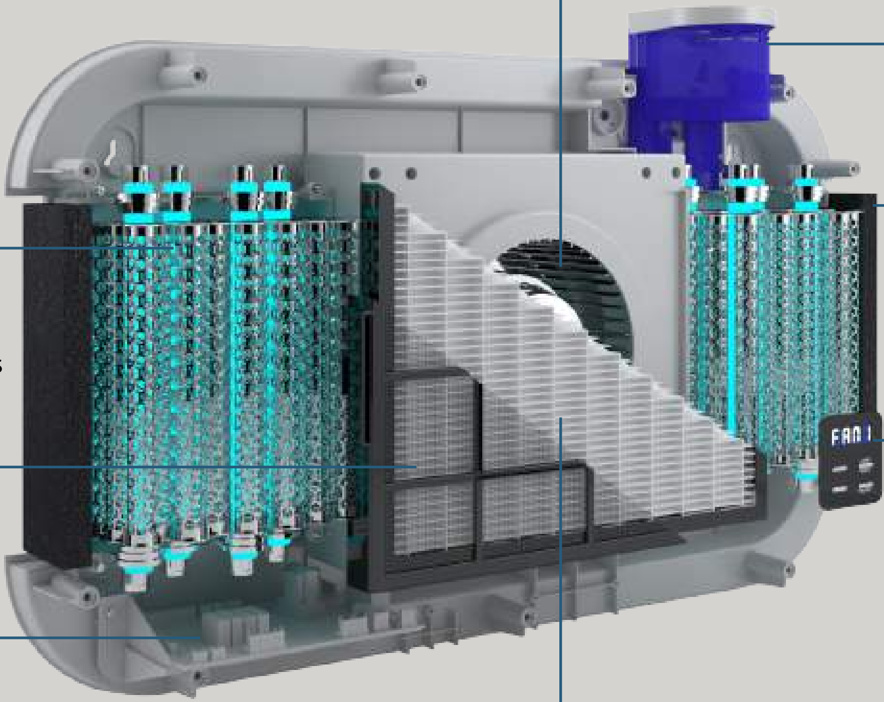
Chinese air purifier standard 21551.3-2010 requires ozone concentrations not to exceed 0.1mg/m³.

Canada

Canadian air purifier standards C22.2 187-15 and CAN/CSA-E60335-2-65:11 requires ozone concentrations not to exceed 50ppb.

Appendix E

RADIC8 - TECHNICAL SPECIFICATIONS, TEST RESULTS AND SUPPORTING MATERIALS



Weight 8 KG	Dimension in mm 380 H x 165 D x 640 W	Noise 38 - 44 dB
Coverage 60 square meters	Surface stood or wall hung	Remote Control Included
Carbon filter change - 8000 hours	Reactor cell change - 8000 hours (alarm)	HEPA filter change - 2000 hours
Max electricity - 95 W	Eligible for We Share Clean Air certification	Airflow 70 - 141 CFM

The VK Blue is compact and full of air cleaning technology, delivering unparalleled results in its class.

HEALTHCARE / DENTISTS / HOSPITALITY / ELDER CARE / CHILD CARE / OFFICE
VETERINARIAN / EDUCATION / SALON / EMERGENCY AID / MILITARY / FRESH PRODUCE

Test Results and Certifications

Specifications of VIRUSKILLER

As of 28th of May, 2017

Description		VK-MEDI	VK-102	VK-002	VK-Blue	HEXTIO	Remarks
General	Elec. Power	AC 220V/120V	AC 220V/120V	AC 220V/120V	AC 220V/120V	DC 12V	
	Elec. Comsuption	Max 280 watt	Max 350 watt	Max 280 watt	Max 95 watt	Max 15 watt	
	Dimension (mm)	W510 x D400 x H1,590	W320 x D320 x H1,570	W320 x D320 x H1,220	W640 x D165 x H380	W124 x D105 x H330	
	Net Weight	54 Kg	40 Kg	34 Kg	7.5 Kg	1.2 Kg	
	Blower Type	Outrota Sirocco	Outrota Sirocco	Outrota Sirocco	Backward Tubo Fan	Sirocco	
	IAQ Sensor	Fine Dust, TVOC's, Temp.	Fine Dust, TVOC's, Temp.	Fine Dust, TVOC's, Temp.	□	Fine Dust, TVOC's	
Reactor	UVC lamp	16 watt, 8 ea	6 watt, 16 ea	6 watt, 8 ea	6 watt, 8 ea	7 watt, 1 ea	
	TiO2 nano Tube Filter	About 70 ea	About 135 ea	About 70 ea	About 40 ea	10 ea	
	Filter Reflector	Chrome Coat	Chrome Coat	Chrome Coat	Chrome Coat	Chrome Coat	
	Case Reflector	Galvanize Reflector	Aluminium Reflector	Aluminium Reflector	Chrome Coated Mirror	Sheet Mirror	
Filtration	HEPA Filter	150 mm, 99.97%	50 mm, 99.97%	50 mm, 99.97%	20 mm, 85%	□	
	Meduim Filter	75 mm, 85%	25 mm, 85%	25 mm, 85%	□	□	
	Actived Carbon Filter	Honeycomb, 20 mm	Honeycomb, 20 mm	Honeycomb, 20 mm	Activated Carbon 20mm	Urethane Carbon, 10 mm	
	Pre-Filter (Net Mesh)	5 mm	5 mm	5 mm	5 mm	□	
CADR	CADR (Q)	1,069 □/hr	653 □/hr	534 □/hr	204 □/hr	□	
	AIR FLOW RATE (V)	1,080 □/hr	660 □/hr	540 □/hr	240 □/hr	□	
	Collection Effieiency (Kη)	99%	99%	99%	85%	□	
	Noize	54.5 dB Max	47.7 dB Max	46.5 dB Max	46. 1dB Max	44 dB Max	
Noxious Gas Removl Rate	Formaldehyde, HCHO	0.70 □/min	95%	82%	71%	65%	
	Amonia, NH3	0.15 □/min	79%	81%	63%	53%	
	Toluene, C6H5CH	1.70 □/min	100%	100%	100%	96%	
	Nitrogen Dioxide, NO2	More than 99.5%	99.50%	99.5%	98.50%	81%	
	Acetaldehyde, CH3CHO	Not yet tested	100%	100%	88%	Not yet tested	
	Acetic Acid, CH3COOH	Not yet tested	100%	100%	100%	Not yet tested	
OzoneEmission Concentration		Below 0.005 µmol/mol	No Detection	No Detection	No Detection	□	
Inactivation of major airborne viruses	Polio Virus	More than 99.99%	More than 99.99%	More than 99.99%	More than 99.99%	□	
	Influenza Virus	More than 99.99%	More than 99.99%	More than 99.99%	More than 99.99%	□	
	Adeno Virus	More than 99.99%	More than 99.99%	More than 99.99%	More than 99.99%	□	
	Corona Virus	More than 99.99%	More than 99.99%	More than 99.99%	More than 99.99%	□	
Removing Ability for Various Bacilluses	Mycobacterium tuberculosis	More than 99.99%	More than 99.99%	More than 99.99%	More than 99.99%	□	
	Staphylococcus aureus	More than 99.99%	More than 99.99%	More than 99.99%	More than 99.99%	□	
	Streptococcus pneumoniae	More than 99.99%	More than 99.99%	More than 99.99%	More than 99.99%	□	
	Escherichia coli DH 5	More than 99.99%	More than 99.99%	More than 99.99%	More than 99.99%	□	
	Klebsiella pneumoniae	More than 99.99%	More than 99.99%	More than 99.99%	More than 99.99%	□	

Electronic Document Version

9696-5225-0960-6759

TEST REPORT

Reissuance (R1)
Date : 2016.08.09

1. No : CT16-087283
2. Client
   - Name : INB air Co.,Ltd.
   - Address : 402, 15, Beotkkot-ro 12-gil, Geumcheon-gu, Seoul, Korea
3. Date of Test : 2016.07.29 ~ 2016.08.09
4. Use of Report :
5. Test Sample : VK-002
6. Test Method
   (1) SPS-KACA002-132:2016
7. Test Results
   1) VK-002

Test Item(s)	Unit	Test method	Test Results	Remark
Noxious Gas Removal Ratio(Nitrogen Dioxide, NO_2	%	(1)	More than 99.5	(21 ± 1) ℃ (45 ± 5) % R.H.

※ Test Mode : FAN3(Rated Air Flow Rate)

---- End of Report ----

Affirmation	Tested By Name : Sang Kyun Park	Technical Manager Name : Jin Sung Park

Our report apply only to the standards or procedures identified and to the sample(s) tested unless otherwise specified. The test results are not indicative of representative of the qualities of the qualities of the lot from which the sample was taken or of apparently identical or similar products.

2016.08.09

Korea Conformity Laboratories President Kyung Sik Kim

Address : 08503 199, Gasan digital 1-ro, Geumcheon-gu, Seoul, Korea 82-2-2102-2500
Result Inquiry : Electric & Electronic Team 82-2-2102-2719

QP-20-01-07(4)

Please check the specification chart on the first page of this document for the individual test results such as the one opposite. If copies of these are required please be specific for which model and which test and we will provide them.

Please enquire about our conformity certification. All of our products are KCC and CE certified, we are also going through UL certification during 2017.

We adhere to the highest electrical safety standards and tailor units dependent on the geographical locations electricity requirements

CE

EC Declaration of Conformity
According to EC EMC Directive 2014/30/EU

Applicant's Name	:	INBair Co., Ltd
Applicant's Address	:	15 Beotkkot-ro 12-gil, Geumcheon-gu, Seoul, Korea
Manufacturer's Name	:	INBair Co., Ltd
Manufacturer's Address	:	15 Beotkkot-ro 12-gil, Geumcheon-gu, Seoul, Korea

Declares that the product:

Product Name	:	Air Purifier
Base Model	:	HEXTIO
Variant Model	:	-

To which this declaration relates is in conformity with the following standard(s) or other normative document(s);

EN 55014-1:2006/A2:2011	Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus - Part 1: Emission
EN 55014-2:2015	Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus - Part 2: Immunity
EN 61000-3-2:2014	Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current <= 16 A per phase)
EN 61000-3-3:2013	Electromagnetic compatibility (EMC) - Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current <= 16 A per phase and not subject to conditional connection

following the provisions of Directive(s);

2014/30/EU Council Directive on the approximation of laws of the Member States relating to electromagnetic compatibility (OJ L13923.5.89); amended by Directives, 92/31/EEC (OJ L126 12.5.92) and 93/68/EEC(OJ L220 30.8.93)

Korea / 05. 10. 2017
(Place and date of issue) (name and signature or equivalent making of authorized person)
European Contact (for regulatory topics only):

www.Radic8.com

MRSA Test Results from Korea Test Institute (KTL)

1. Test Method: KOA AS 01 is the test standard for Korea Air Sterilizer Association.

Description		Contents	Remarks
Test Code		KOA AS 01	
Airborne Bacteria Sterilization Performance	Test Chamber	60±0.5 m^3	
	Test Strain	Staphylococcus epidermidis (ATCC 12228)	
	Incubating Time	24 Hours	
	Removal Rate Calculation Formula	$N_i=(1-S_c/C_i) \times 100$	
	Test Laboratory	Korea Test Institute (KTL)	
Hazardous Gas Removal Performance	Test Chamber	4.0±0.1 m^3	
	Measuring Instrument	FT-IR	
	Test Gases	5 kinds of Gases (Toluene, Ammonia, Acetaldehyde, Formaldehyde, Acetic Acid)	
	Measuring Time	120 Minutes	
	Removal Rate Calculation Formula	$\eta_{i,n} = 1 - C_{i,n}/C_{i,o} \times 100$	
	Test Laboratory	Korea Test Institute (KTL)	
Ozone Emission Test	Test Chamber	27 m^3	
	Measuring Instrument	Ozone Concentration Analyzer	
	Measuring Method	Real-time Continuous Measurement	
	Test Laboratory	Korea Basic Electric Power Research Institute	
Noise Measure Test	Test Chamber	Anechoic Room	
	Measuring Position	1m Height	
	Calculation Method	The average value of the front portion, the rear portion, the left and right side portions, the rear portion	
	Test Laboratory	Korea Test Institute (KTL)	

2. Test Results

Description		Limit of KOA AS 01	Test Results of VIRUSKILLERS			Remarks
			VK-BLUE	VK-001 and VK-002	VK-102 and VK-102	
Release of Harmful Substances	Particulate matter	4.0 under	0.052	0.083	0.083	mg/hr
	TVOC's	18.0 under	0.276	0.088	0.088	
	Acetaldehyde	1.8 under	0.037	0.024	0.024	
	Formaldehyde	1.8 under	0.184	0.063	0.063	
Airborne Bacteria Removal Rate		**80% over**	**96.3 %**	**99.1%**	**99.4%**	60 min
Harmful Gas Deodorization Rate	Ammonia	30% over	63%	81%	79%	120 min
	Acetic Acid	30% over	100%	100%	100%	
	Toluene	30% over	100%	100%	100%	
	Acetaldehyde	30% over	88%	100%	100%	
	Formaldehyde	30% over	71%	82%	95%	
Ozone Release		0.05×10^{-6} under	-0.02ppm (Below "0" means no detection)	-0.016ppm (Below "0" means no detection)	-0.014ppm (Below "0" means no detection)	8 hr
Noise		50 dB	46.1dB	46.5dB	47.7dB	

Appendix F

AERAMAX PROFESSIONAL (FELLOWES BRANDS) - TECHNICAL SPECIFICATIONS, TEST RESULTS AND SUPPORTING MATERIALS

PACKAGING CONTENTS

- AeraMax® PRO Air Quality Control System
- True HEPA Filter with AeraSafe™ Antimicrobial Treatment (1 filter)
- Activated Carbon Filter w/Pre-Filter (1 of each filter)
- Keys for Locking Front Panel (2)
- Mounting Template
- Pan Head Phillips Screws - M6 x 50mm (4)
- Drywall Anchors - 10mm OD (4)
- Registration information

PRODUCT SPECIFICATIONS

AeraMax® PRO AM VI	
Dimensions (H x W x D)	19.6 x 34.7 x 9 inches / 49.7 x 88.1 x 22.8 cm
Weight of System (including filters)	33.3 lbs. / 15.1 kg
Power Requirements	120 volt, 60 Hz, 2 amp
Power Consumption (5 fan speeds)	8, 12, 18, 35, 166 watt
Air Delivery (5 fan speeds)	153, 186, 224, 280, 440 CFM
Decibels	42, 44, 51, 53, 68 dB
Display	Capacitive Touch, Internal Access Only
Sensors	EnviroSmart™
Sensor Controlled Operation Modes	2 Primary modes - Normal Mode and Quiet Mode
Supplied Filters	2 True HEPA Filters with AeraSafe™ Antimicrobial Treatment with an estimated average filter life of 1 year, 2 Activated Carbon Filters with Pre-Filter, estimated average filter life 6 months.
Cleaning System	High Efficiency Particulate Air (HEPA) filter rated efficiency of 99.97% of airborne particulate at 0.3 microns. Carbon Filter adsorbs odor and volatile organic compounds, PlasmaTRUE™ bipolar ionizer.
Color	• Stainless (item# 9416301), • White (item# 9446201), • Graphite (item #9446301), • Custom finish available, call for more details

REPLACEMENT FILTERS	
HEPA	True HEPA filter replacement with AeraSafe™ treatment. Average filter life 2 years: 9416601 – 2 pack
Carbon	Granular activated carbon replacement filter with pre-filter. Average filter life 6 months: 9416501 – 4 pack

For additional replacement filter and accessory information please visit: www.aeramaxpro.com

INFORMATION TO THE USER

This equipment has been tested and found to comply with the limits for Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in an installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna
- Increase the separation between the equipment and receiver
- Connect the equipment on a circuit different from that to which the receiver is connected.
- Consult the dealer or experienced radio/TV technician for help.

WARNING: Any changes or modifications not expressly approved by the manufacturer could void the user's authority to operate the equipment and warranty.

# AERAMAX PRO AM 3 PC	# AERAMAX PRO AM 4 PC

CLEANS up to 65m²

CLEANS 600 TO 130m²

SPECIFICATIONS (AM 3 PC)

Weight of system (including filters)	9.16 kg
Air Delivery, 5 speeds (CFM)	76, 93, 112, 140, 220
Sound pressure levels, each fan speed (dB)	38, 41, 48, 52, 67
Power Requirements:	220 – 240V , 60Hz, 2A
Power Consumption:	175W
Electrical safety certification	UL,TUV,GS,CE
Motor	Single motor: encased brushless DC motor, thermal and overcurrent protection, designed for low noise, long-term continuous use at high RPM
Air intake / outlet	Bottom / Top
Control panel	Display Dual Button Control TFT LCD Screen
Housing material	UV stabilised ABS
Operating temperature / humidity level	41 to 104F (5 to 40C) / Up to 60%
Warranty	5 Year Limited Warranty

DIMENSIONS (AM 3 PC)

Wall mount	508 x 533 x 228 mm
Floor stand	576 x 533 x 270 mm

CONFIGURATIONS (AM 3 PC)

AM 3 PC - Wall mount	**ITEM NUMBER: 9573801**
AM 3S PC - Floor stand	**ITEM NUMBER: 9574001**

SPECIFICATIONS (AM 4 PC)

Weight of system (including filters)	15.1 kg
Air Delivery, 5 speeds (CFM)	153, 186, 224, 280, 440
Sound pressure levels, each fan speed (dB)	42, 44, 51, 53, 68
Power Requirements:	220 – 240V , 60Hz, 2A
Power Consumption:	175W
Electrical safety certification	UL,TUV,GS,CE
Motor	Dual motors: encased brushless DC motor, thermal and overcurrent protection, designed for low noise, long-term continuous use at high RPM
Air intake / outlet	Bottom / Top
Control panel	Display Dual Button Control TFT LCD Screen
Housing material	UV stabilised ABS
Operating temperature / humidity level	41 to 104F (5 to 40C) / Up to 60%
Warranty	5 Year Limited Warranty

DIMENSIONS (AM 4 PC)

Wall mount	497 x 881 x 228 mm
Floor stand	576 x 884 x 269 mm

CONFIGURATIONS (AM 4 PC)

AM 4 PC - Wall mount	**ITEM NUMBER: 9573901**
AM 4S PC - Floor stand	**ITEM NUMBER: 9573301**

PureView™ For more information, visit aeramaxpro.com/uk

AERAMAX® PROFESSIONAL

Fellowes Brands
Fellowes Ltd. | Unit 2 Ontario Drive New Rossington | Doncaster | United Kingdom
DN11 0BF | 00800 18101810

CERTIFICATE

Independently tested by

airmid healthgroup

airmidhealthgroup.com

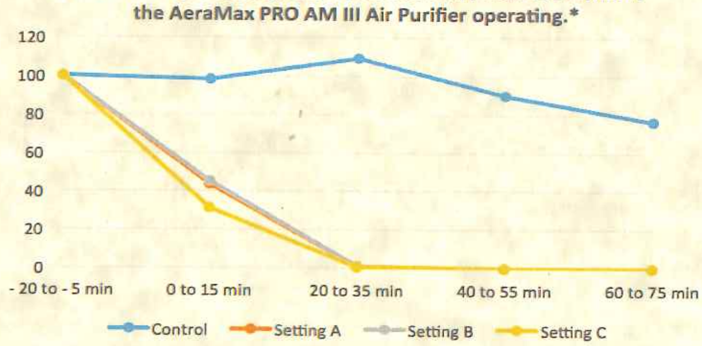
The following products have been tested by airmid healthgroup ltd as outlined in report(s) ASCR092102v2

Product Description	AeraMax Pro AMIII
Manufacturer	Fellowes
Certification Number	AHGC: 92102/15/05/08/2080/01
Validation Period	1 Year
Outline of Test Method	Determination of removal efficiency of Influenza A (H1N1) following aerosolisation of the virus into a 20 m^3 environmental test chamber.
Additional SKUs	AeraMax Pro AMIIIS, AM3 PC, AM3S PC AeraMax Pro AMIV, AMIVS, AM4 PC, AM4S PC

RESULTS

The Fellowes AeraMax Pro has been shown to remove 99.9% of airborne virus within 35 minutes of operation

Influenza A percentage reduction over time with and without the AeraMax PRO AM III Air Purifier operating.*



*Results represent the average of n=3 runs. Device settings A: ionizer ON and filter low speed; device setting B: ionizer off and filter at low speed; device setting C ionizer on and filter at high speed.

16/5/19

Dr Bruce Mitchell
Chairman/CEO
airmid healthgroup Ltd

Dated

airmid healthgroup

Airmid Health Group Ltd Unit 17 Trinity Enterprise Campus Macken Street Dublin 2
Tel +353 1 633 6820 email info@airmidhealthgroup.com www.airmidhealthgroup.com

Referenced to Report No(s): **ASCR092102v2**

Certificate not valid without above official seal

CERTIFICATE

Independently tested by

airmid healthgroup

airmidhealthgroup.com

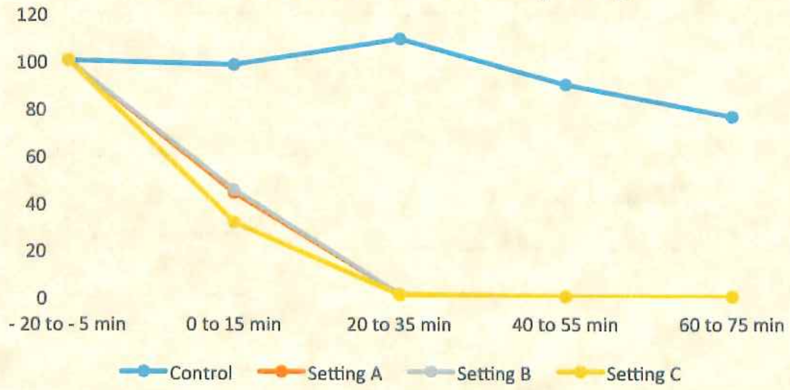
The following products have been tested by airmid healthgroup ltd as outlined in report(s) ASCR092102v2

Product Description	AeraMax Pro
Manufacturer	Fellowes
Certification Number	AHGC: 92102/15/05/08/2080/01
Validation Period	1 Year
Outline of Test Method	Determination of removal efficiency of Influenza A (H1N1) following aerosolisation of the virus into a 20 m³ environmental test chamber.

RESULTS

The Fellowes AeraMax Pro has been shown to remove 99.99% of airborne virus within 35 minutes of operation.

Influenza A percentage reduction over time with and without the AeraMax PRO AM III Air Purifier operating.*



*Results represent the average of n=3 runs. Device settings A: ionizer ON and filter low speed; device setting B: ionizer off and filter at low speed; device setting C ionizer on and filter at high speed.

16/5/2017

Dr Bruce Mitchell
Chairman/CEO
airmid healthgroup Ltd

Dated

CERTIFICATE OF COMPLIANCE

Certificate Number	20150113-E349375
Report Reference	E349375-20141115
Issue Date	2015-JANUARY-13

Issued to: FELLOWES INC
1789 NORWOOD AVE
ITASCA IL 60143-1059

This is to certify that representative samples of ION GENERATORS
Air Purifier, Models AeraMax PRO AM III, AeraMax PRO AM IIIS, AeraMax PRO AM IV and AeraMax PRO AM IVS.

Have been investigated by UL in accordance with the Standard(s) indicated on this Certificate.

Standard(s) for Safety: UL 867 - STANDARD FOR ELECTROSTATIC AIR CLEANERS
CSA C22.2 NO. 187-09 - ELECTROSTATIC AIR CLEANERS

Additional Information: See the UL Online Certifications Directory at www.ul.com/database for additional information

Only those products bearing the UL Certification Mark should be considered as being covered by UL's Certification and Follow-Up Service.

Look for the UL Certification Mark on the product.

Bruce Mahrenholz, Assistant Chief Engineer, Global Inspection and Field Services

UL LLC

Appendix G

AIRLABS - TECHNICAL SPECIFICATIONS, TEST RESULTS AND SUPPORTING MATERIALS

TECHNICAL SPECIFICATIONS

Model	u.m.	1200
Capacity		
1st speed	m3/h	300
2nd speed	m3/h	700
3rd speed	m3/h	1200
Noise		
1st speed	dB	38
2nd speed	dB	41
3rd speed	dB	51
Consumption	W	125
Power Input	V-Hz	230 - 50/60
Dimensions AxBxC	mm	468x303x840
Weight	Kg	30

CONTROLLER TECHNOLOGY

The airbubbl home's microprocessor independently controls the performance of the electrostatic precipitator (ESP) so that the filtration level is automatically adjusted to the specific operating condition.
The system is managed via the control panel. Here, faults are reported and it is indicated when the electrostatic cells must be cleaned. The electronic parts of the machine are protected assuring total reliability. All the user has to do is switch on the airbubbl home and select the most appropriate speed for his/her requirements.

Airlabs

Airlabs

airbubbl home

DESCRIPTION

The airbubbl home is an indoor air cleaner designed to provide clean air, free of particles and toxic gases to customers at home, at work, in schools, nurseries and hospitals. The airbubbl home uses the latest technology in particle and gas removal to ensure the optimal benefits for the users' health and well-being. The unit has a plug-and-play functionality and is set up in minutes. It provides superb air filtration specifications, is easy to maintain and comes with low cost of operation.

Common urban air pollution contains of particles and gases. Particles differ in size and it's important to remove a range of sizes as wide as possible to have the maximum health effect. The airbubbl home filters particles use an electrostatic precipitator (ESP). The efficiency of electrostatic filters is practically independent of particle-size - unlike that of other technologies. That means it removes particles of any size, including the smallest and potentially harmful nanoparticles. This technology is well-established and used in many industrial applications.

The urban pollution mix also contains toxic gases such as NO_2, SO_2, VOCs, NH_3 and Ozone. Nitrogen dioxide (NO_2) is a harmful gas that is produced by combustion processes such as in car engines. Due to an abundance of diesel cars in major cities like London, NO_2 concentrations regularly exceed regulatory threshold values. Ozone is another harmful gas produced both outdoors and indoors. Both NO_2 and ozone are leading causes for respiratory diseases in the UK and elsewhere. Volatile organic compounds (VOCs) are produced by plants, people, furniture, cleaning products, etc. They can cause harm directly or lead to secondary particle formation. Sulphur dioxide (SO_2) and ammonia (NH_3) among others are found at more specific locations like ports or farms. They can be harmful and a nuisance.

Gases are removed in airbubbl home by Airlabs' proprietary ENC filter. The ENC filter is a specially treated pollution filter that removes toxic gases such as NO_2, SO_2, VOCs, NH_3 and Ozone. The patented ENC filter consists of engineered carbon that has been physically and chemically modified to effectively remove a large amount of pollutants. The ENC filter has been optimised to create a low pressure drop and a high removal efficiency while not supporting any bacterial growth.

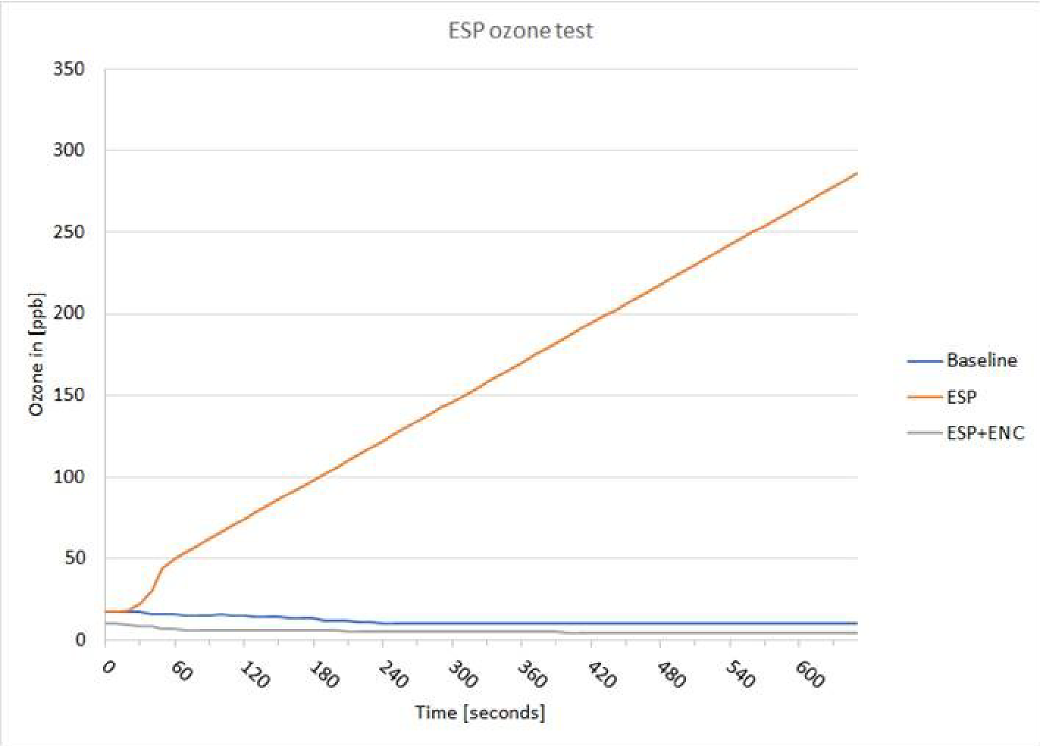
The airbubbl home is operated directly on the unit or via infrared remote control. The user can use the remote to select one of the three operating speeds just with a press of the button.

PERFORMANCE

	NO_2	OZONE	VOCs	SO_2
Removal efficiency[1] /%	95	98	60	71

[1] At lowest speed.

EQUIPMENT, PERFORMANCE AND CONTROLS	AIRBUBBL HOME
Dual voltage electrostatic filtering	✓
CPU for real-time function management	✓
Filtering performance control and management	✓
Activation of functions using the IR remote control	✓
Automatic restart following a power blackout	✓
Control LED check-up button	✓
Alarm light for routine maintenance	✓
Pre-alarm light for routine maintenance	✓
Fault warning light	✓
Filtration performance warning light	✓
Dual voltage electrostatic filtering	✓
Warranty on electronic components (for manufacturing defects)	3 years
Warranty on the motor/s (for manufacturing defects)	3 years
1st speed filtration performance (on PM2.5)	99%
2nd speed filtration performance (on PM2.5)	98%
3rd speed filtration performance (on PM2.5)	96%
Performance tolerance	±1%



Airlabs

Airlabs

airbubbl home

PRODUCT DATA SHEET

The Airlabs Re-Engineered Nano-Carbon Filter (ENC) for HVAC systems (Stella McCartney HQ – Bond Street)

In this case our ENC filter has been installed into the new HQ of Stella McCartney in London. The filter is designed to generate a lot of clean air with a minimum size and pressure drop. The ENC filters is the best available technology in terms of performance for a wide variety of pollutants, low pressure drop, durability and capacity.

The ENC filter will protect both customers and staff inside the Stella McCartney store from the toxic cocktail of pollution while keeping the energy consumption low. We do that by having a suite of treatment strategies combined with a proprietary filter design that is able to reduce the pressure drop of the filter while enhancing filter performance. In the Stella McCartney HQ several filters are placed in V-shapes to optimize the performance and to meet the customer demands on pressure drop and airflow.


The Filter

The Filter Unit

EMCEL Filters a UK based company have build the filter shell and the trays while the ENC filter from Airlabs is used to filtrate the pollution. The filter solution has 10 ENC filters that are placed in 5 V-shapes to optimize the performance. Each filter has a dimension of 600 x 200 mm while the dimensions of the shell are 595 H x 595 W x 350 L mm. The filter needs a withdrawal access of 650 mm on one side to enable the ENC filter change. The Stella McCartney HVAC system has an air flow of 1800 m3/h. This results in a face velocity of around 0.5 m/s at these air flows are the performance of the ENC filters very high see below.

Benefits of installing an ENC HVAC-Filter alongside existing infrastructure

1) Extremely low pressure drop

2) Very high NO2 capacity

3) Low Energy Consumption whilst treating a Large Volume of Air

4) Developed to address a complex mix of pollutants.

Airlabs

The ENC HVAC filter has been specifically optimised to allow for a high removal rate of NO_2, Ozone, Ammonia and BTEX. This protects people from exhaust pollutants found in urban cities that often find their way into buildings.

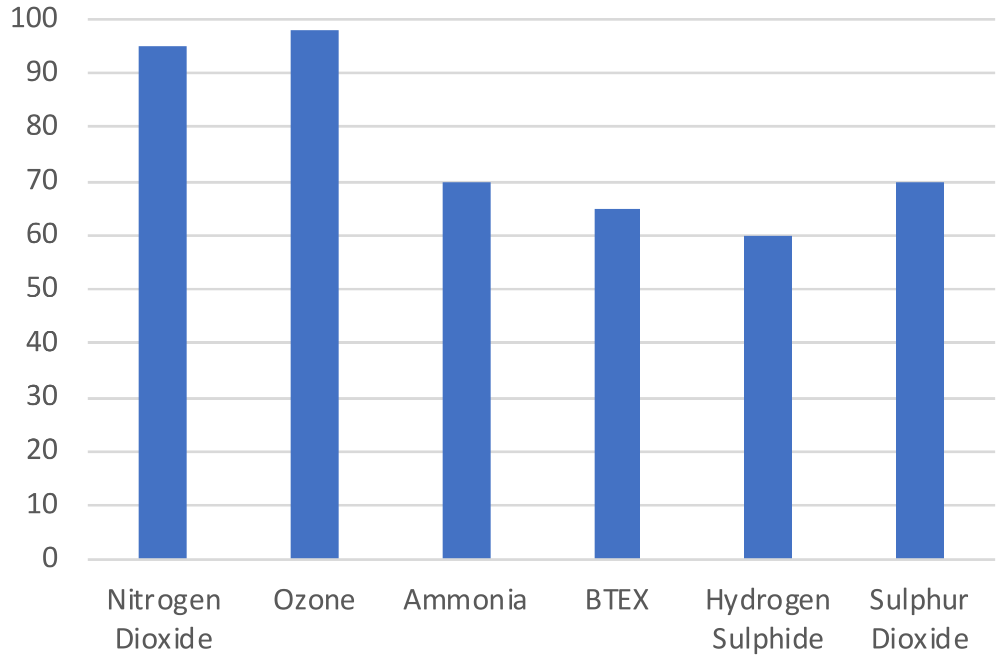
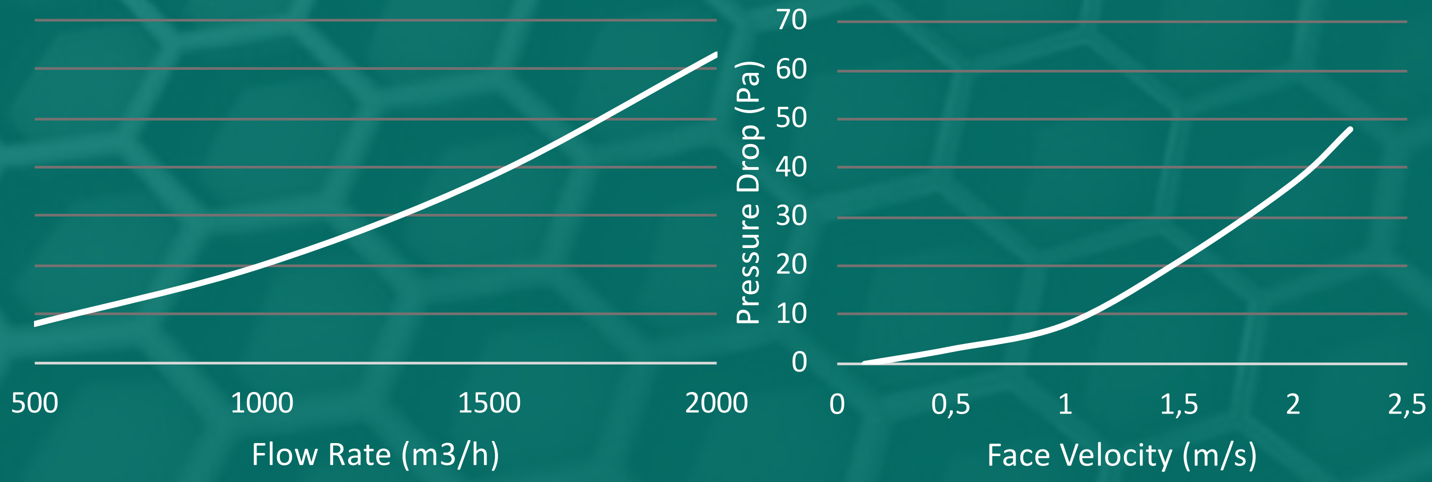


*Figure shows the removal efficiency (RE%) in % of nitrogen dioxide (NO_2, >95%), Ozone (O_3, >98%), ammonia (NH_3, 70%), BTEX compounds (benzene 65%, toluene 70% and xylene 45%), Hydrogen Sulfide (H_2S, 60 %) and Sulfur dioxide (SO_2, 70%). *Other Airlabs filters can provide higher removal for specific gases such as formaldehyde. All removal efficiency and pressure drop tests are performed in Airlabs lab facilities.*

Easy integration with low pressure drop:

The macro-porous structure of the ENC filter provides the lowest pressure drop in the market meaning it can easily be integrated into existing systems. A low pressure drop also allows for a low energy consumption.



Airlabs

Appendix H

RAW DIFFUSION TUBE RESULTS

NELL GWYNN

The raw diffusion tube results for the monitoring period at Nell Gwynn are displayed in table below.

Sampling Month	Raw NO_2 Concentration (µg/m^3)	
	AFS	'Control'
1	17.91	16.57
2	20.12	19.51
3	16.06	15.88
4	18.18	18.94
5	13.05	14.19
6	16.72	15.28
Period Mean	17.0	16.7

COLUMBIA MARKET

The raw diffusion tube results for the monitoring period at Columbia Market are displayed in table below.

Sampling Month	Raw NO_2 Concentration (µg/m^3)	
	AFS	'Control'
1	22.90	22.25
2	18.56	16.01
3	22.33	21.01
4	20.44	20
5	17.49	18.48
6	*	19.21
Period Mean	20.3	19.5

* - Diffusion tube not recovered

RACHEL MCMILLAN

The raw diffusion tube results for the monitoring period at Rachel McMillan are displayed in table below.

Sampling Month	Raw NO_2 Concentration (µg/m^3)	
	AFS	'Control'
1	14.8	*
2	19.06	19.19
3	*	*
4	*	*
5	*	*
6	*	*
Period Mean	16.9	19.2

* - Diffusion tube not recovered

PEMBURY HOUSE

The raw diffusion tube results for the monitoring period at Pembury House are displayed in table below.

Sampling Month	Raw NO_2 Concentration ($\mu g/m^3$)	
	AFS	'Control'
1	12.37	*
2	14.21	13.06
3	12.46	17.21
4	7.95	18.97
5	9.79	19.37
6	*	*
Period Mean	11.4	17.2

* - Diffusion tube not recovered

THOMAS CORAM

The raw diffusion tube results for the monitoring period at Thomas Coram are displayed in table below.

Sampling Month	Raw NO_2 Concentration (µg/m^3)	
	AFS	'Control'
1	15.59	19.59
2	14.35	16.5
3	15.63	17.71
4	17.11	18.78
5	13.92	14.37
6	14.94	17.92
Period Mean	15.3	17.5

DOROTHY GARDNER

The raw diffusion tube results for the monitoring period at Dorothy Gardner are displayed in table below.

Sampling Month	Raw NO_2 Concentration (µg/m^3)	
	AFS	'Control'
1	22.59	19.27
2	22.82	18.95
3	19.52	20.42
4	*	*
5	*	*
6	*	*
Period Mean	21.6	19.5

* - Diffusion tube not recovered

The raw diffusion tube results for the baseline NO_2 survey undertaken at twenty nursery schools throughout London from December 2018 – March 2019 are shown in the table below:

Nursery School	Sampling Month	Raw NO_2 Concentration (μg/m^3)				
		Roadside	Entrance (External)	Playground	Classroom	Entrance (Internal)
Alice Model Nursery School	1	42.71	33.11	37.16	15.38	26.22
	2	49.23	38.29	41.85	-	29.04
	3	47.60	38.37	39.13	22.85	32.65
	Period Mean	46.5	36.6	39.4	19.1	29.3
Ann Bernadt Nursery School	1	34.11	31.35	34.66	26.33	26.25
	2	37.71	32.34	36.61	-	29.16
	3	25.68	23.33	27.59	-	20.78
	Period Mean	32.5	29.0	33.0	26.3	25.4
Clyde Nursery School	1	37.85	34.35	35.7	20.74	22.84
	2	33.38	32.20	30.00	18.61	19.92
	3	5.55	26.51	26.77	16.18	19.31
	Period Mean	25.6	31.0	30.8	18.5	20.7
Columbia Market Nursery School	1	43.47	40.32	35.23	23.34	32.14
	2	44.81	43.1	25.81	34.57	33.04
	3	<0.63	<0.63	1.11	0.63	1.23
	Period Mean	44.1	41.7	20.7	19.5	22.1
Dorothy Gardner Centre	1	40.27	35.8	40.44	25.34	23.08
	2	39.89	34.39	33.51	25.63	22.48
	3	25.68	23.33	27.59	-	20.78
	Period Mean	35.3	31.2	33.8	25.5	22.1
Ethelred Nursery School and Children's Centre	1	41.16	36.83	35.71	15.87	20.21
	2	41.1	39.46	34.32	16.74	19.99
	3	36.66	35.54	32.60	10.67	-
	Period Mean	39.6	37.3	34.2	14.4	20.1

Nursery School	Sampling Month	Raw NO_2 Concentration (µg/m^3)				
		Roadside	Entrance (External)	Playground	Classroom	Entrance (Internal)
Golborne Children's Centre	1	37.28	39.8	34.17	16.5	17.06
	2	42.56	-	35.77	20.71	22.98
	3	47.19	43.25	-	22.54	25.81
	Period Mean	42.3	41.5	35.0	19.9	22.0
Kaye Rowe Nursery School and Children's Centre	1	37.5	33.83	-	14.31	17.18
	2	38.80	39.39	-	18.74	20.44
	3	45.78	36.92	-	19.19	20.56
	Period Mean	40.7	36.7	-	17.4	19.4
Kintore Way Nursery School and Children's Centre	1	54.98	44.25	36.38	21.96	30.48
	2	55.04	44.18	35.36	21.70	29.32
	3	41.11	34.59	26.01	17.65	18.04
	Period Mean	50.4	41.0	32.6	20.4	25.9
Maxilla Children's Centre	1	36.37	39.19	35.13	16.94	17.14
	2	45.9	-	35.31	20.31	22.25
	3	45.72	42.98	-	23.60	25.11
	Period Mean	42.7	41.1	35.2	20.3	21.5
Nell Gwynn Nursery School	1	50.87	36.16	34.96	29.03	26.11
	2	49.36	38.79	33.44	28.11	26.05
	3	41.37	30.19	29.47	22.41	21.04
	Period Mean	47.2	35.0	32.6	26.5	24.4
Pembury House Nursery School	1	62.11	45.07	39.11	26.24	22.9
	2	70.67	42.14	36.22	-	22.16
	3	58.54	34.78	-	18.75	19.66
	Period Mean	63.8	40.7	37.7	22.5	21.6
	1	40.4	39.45	36.02	28.66	22.17

Nursery School	Sampling Month	Raw NO_2 Concentration (µg/m³)				
		Roadside	Entrance (External)	Playground	Classroom	Entrance (Internal)
Rachel McMillan Nursery School and Children's Centre	2	-	35.31	35.33	23.93	21.83
	3	32.69	31.47	27.99	24.06	20.09
	Period Mean	36.5	35.4	33.1	25.6	21.4
Robert Owen Nursery School and Children's Centre	1	38.51	36.87	34.46	25.34	27.96
	2	36.49	35.81	33.17	24.10	26.31
	3	29.56	29.07	26.75	8.11	21.66
	Period Mean	34.9	33.9	31.5	19.2	25.3
Sheringham Nursery School and Children's Centre	1	34.6	38.59	29.04	18.92	29.26
	2	45.21	41.45	38.50	-	28.59
	3	34.65	32.77	30.06	12.33	24.25
	Period Mean	38.2	37.6	32.5	15.6	27.4
Somerset Nursery School and Children's Centre	1	39.58	33.75	30.77	16.58	-
	2	-	-	-	-	-
	3	-	-	-	-	-
	Period Mean	39.6	33.8	30.8	16.6	-
Tachbrook Nursery School	1	48.9	37.75	40.86	10.44	10.13
	2	50.65	39.54	44.46	12.84	11.26
	3	43.77	30.99	37.06	12.28	10.78
	Period Mean	47.8	36.1	40.8	11.9	10.7
Thomas Coram Centre	1	45.9	35.04	36.2	-	26.1
	2	-	-	-	-	-
	3	35.89	34.67	16.58	23.44	22.36
	Period Mean	40.9	34.9	26.4	23.4	24.2
Triangle Nursery	1	38.79	32.66	35.13	21.03	19.04
	2	37.58	35.68	35.20	20.40	19.80

Nursery School	Sampling Month	Raw NO_2 Concentration (µg/m^3)				
		Roadside	Entrance (External)	Playground	Classroom	Entrance (Internal)
Triangle Nursery	3	30.44	24.90	26.13	16.02	16.70
	Period Mean	35.6	31.1	32.2	19.2	18.5
Windham Nursery School	1	32.94	25.42	28.8	-	21.33
	2	30.29	24.48	26.89	20.53	19.20
	3	33.03	30.52	29.56	20.54	21.66
	Period Mean	32.1	26.8	28.4	20.5	20.7

Key:

* - Diffusion tube not recovered

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