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Air pollution mitigation and resulting indoor:outdoor air quality in and around three London Schools

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Measuring Air Quality 2023

Presentation overview

1. Air quality programme and Acknowledgements
2. Background
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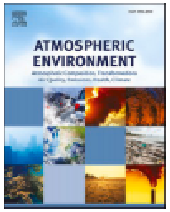

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Investigation of air pollution mitigation measures, ventilation, and indoor air quality at three schools in London

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Acknowledgements and Project Team

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2. **Global Action Plan** - behavioural interventions, schools' engagement, overall programme management.
3. **Arup** - technical advice, support with design & implementation of the physical interventions and modelling the impacts.
4. **University of Surrey** - air quality measurements to investigate the impact of mitigation interventions.
5. **School staff and children** – safe access to schools and interactions.

Impact on Urban Health

global action plan

ARUP

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Air pollution In and Around Schools in the UK

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- 3.1 million children across England attend schools in areas that exceed WHO limits on $PM_{2.5}$.
- More than 1.2 million children in London attend schools in areas that exceed WHO limits for $PM_{2.5}$.
- 98% of schools in London are located in areas exceeding WHO pollution limits, compared to 24% outside of London.
- More than 700,000 children are from primary schools.

(www.London.gov.uk)

Air Pollution Impact on Children's Health

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- Children growing up in polluted London areas showed significantly smaller lung volume, with a loss of ~5% in lung capacity - equivalent to two large eggs - compared to their peers in the rest of England.

- Primary school children are amongst the most at risk, since, at that age, their lungs are still developing, and toxic air can stunt their growth.

- Due to their high physical activities and high breathing rates, they can potentially ingest high levels of air pollution, leading to,
  - Asthma, bronchitis and other respiratory diseases.
  - Adverse effects on brain health.
  - Cognitive function impairment and reduced academic performance.
  - Behavioural problems.

➢ Good quality air is, therefore, vital for the health, comfort, wellbeing and learning for children.

(www.London.gov.uk)

Overall Objectives

Pilot Study: Investigation of air pollution in and around three schools in the London Borough of Lambeth.

– To gain an understanding of:

- The extent of the air pollution problem inside and around schools and the factors that affect them.
- The effectiveness of air pollution mitigation methods.

– To ensure scalability of results and findings to benefit schools across the UK.

Methodology

To achieve the overall objective,

1. Baseline measurements (pre-intervention of mitigation measures) were carried out:
   - Particulate matter (PM_{10}, $PM_{2.5}$ and PM_1).
   - Carbon dioxide (CO_2).
   - Temperature and relative humidity (thermal comfort parameters).
   - Ventilation rates (from the CO_2 measurements).

2. Implementation of air pollution mitigation measures in collaboration with the partners.

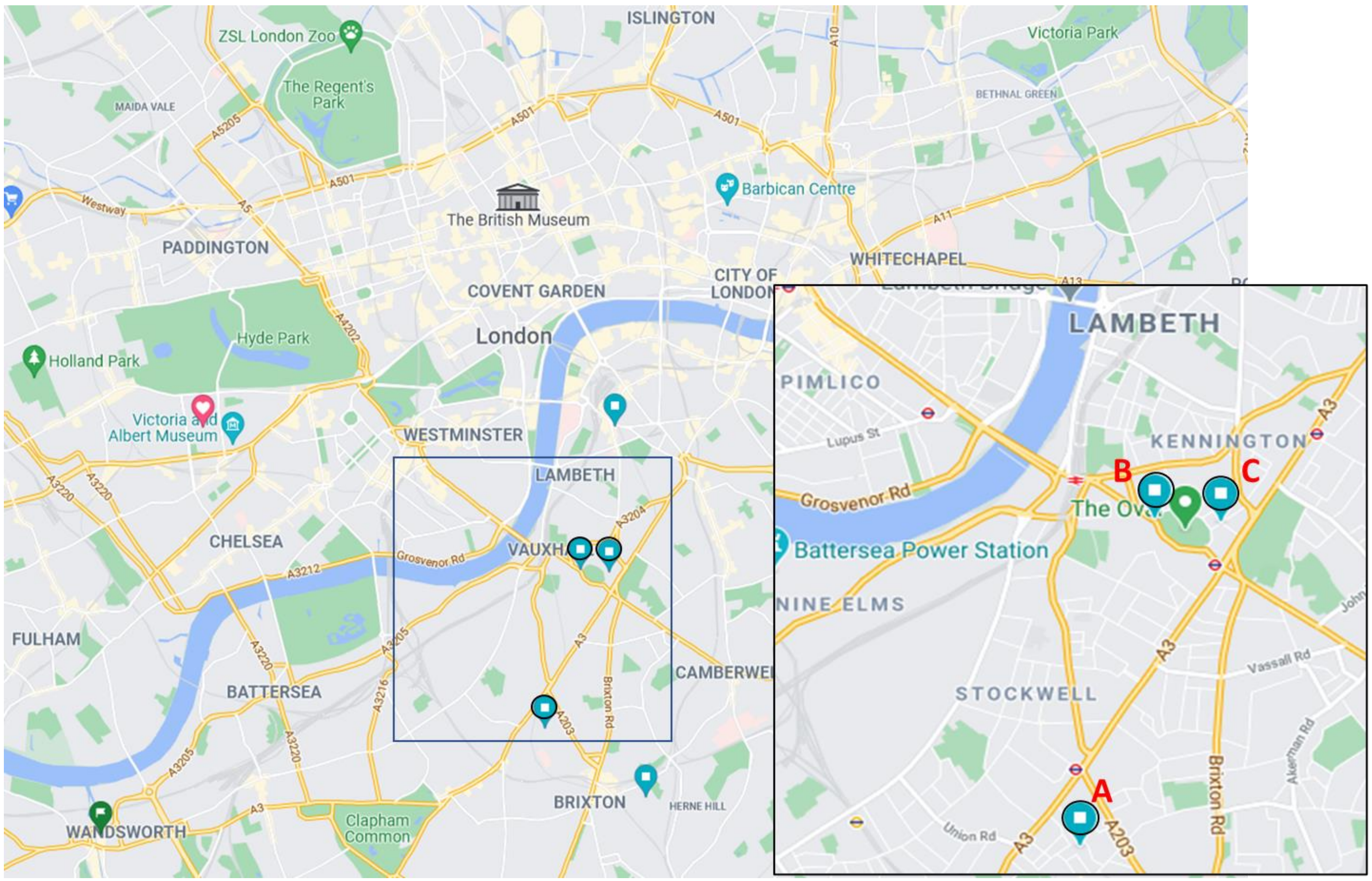
3. Post-intervention measurements were carried out of the same parameters to understand the effects of implementing the mitigation measures.

Parameters Measured and Instrumentation

Air Quality Parameter (unit)	Instrument Used	Measurement Range
PM_1 (µg/m^3) $PM_{2.5}$ (µg/m^3) PM_{10} (µg/m^3)	Electrical Low-Pressure Impactor (ELPI+) Dekati Ltd., Kangasala, Finland)	6 nm – 10µm
PM_1 (µg/m^3) $PM_{2.5}$ (µg/m^3) PM_{10} (µg/m^3)	GRIMM 11-C & EDM 107 (GRIMM Aerosol Technik GmbH & Co KG, Ainring, Germany)	0.22-32 µm
CO_2 (ppm) Temperature (°C) Relative Humidity (%)	Q-TRAK (model 7575; TSI Inc., Shoreview, MN, USA)	0-5000 ppm -10 to 60°C 5 to 95%
CO_2 (ppm) Temperature (°C) Relative Humidity (%)	HOBO MX1102 CO2 logger (Onset Computer Corporation, Bourne, MA, USA)	0 to 5,000 ppm 0° to 50°C 1% to 90%

Location of Monitored Schools

London Borough of Lambeth



Description of Schools and Monitoring Dates

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School	Monitoring dates
School A Primary Voluntary Aided School Mixed gender Age range 4 to 11 189 students. Urban- Away road- Single storey	**Baseline monitoring:** 12-28 May 2021. Monitoring over two lockdown periods: 1) When non-essential retailers, and outdoor hospitality venues allowed. 2) When indoor hospitality and larger outdoor gatherings allowed. **Post-intervention monitoring:** 7-21 June 2021. Educational establishments, indoor hospitality and larger outdoor gatherings allowed.
School B Primary Voluntary Aided School Mixed gender Age range 3 to 11 218 students Urban, Near road, Single storey	**Baseline monitoring:** 19 April - 7 May 2021. Non-essential retailers, public buildings and outdoor hospitality venues allowed. **Post-intervention monitoring:** 28 September - 18 October 2021. All lockdown restrictions were removed.
School C Primary Community School Mixed gender Age range 3 to 11 324 students Urban, Away road, Multi-storey	**Baseline monitoring:** 9 March - 30 March 2021. Schools reopened, but all other lockdown restrictions remained in place. **Post-intervention monitoring:**14 - 24 September 2021. All lockdown restrictions were removed.

Air Pollution Mitigation Methods Investigated

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School

School A
Hedera (ivy) green screens, total length 73.2 m, height 2.2 m installed along the fence in front of the school, shielding the school from traffic.

School B
Two air purifiers were installed in a classroom on opposite sides. Investigated varying modes of operation of fan speeds.

School C
Street on which School C is located was closed off from all vehicular traffic for half a day.

Green Screen

Air Purifiers

School Street

Local Pollutant Sources

– **School A:**
  - Located within a residential area with roads on both sides, but away from busy major roads.

– **School B:**
  - Located close to a busy road and traffic lights.

– **School C:**
  - Located within a residential area with roads on both sides, but away from busy major roads.
  - Kitchen extract discharging into school courtyard.
  - Local minor construction.

Results

School A: Particle Matter (PM) Concentrations

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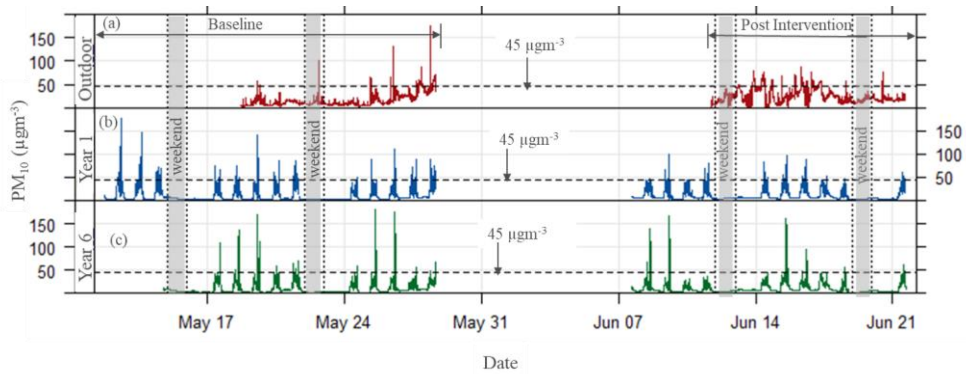

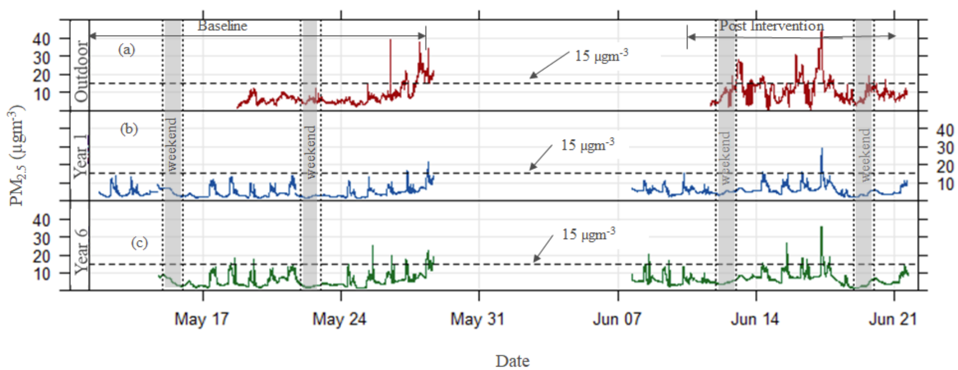

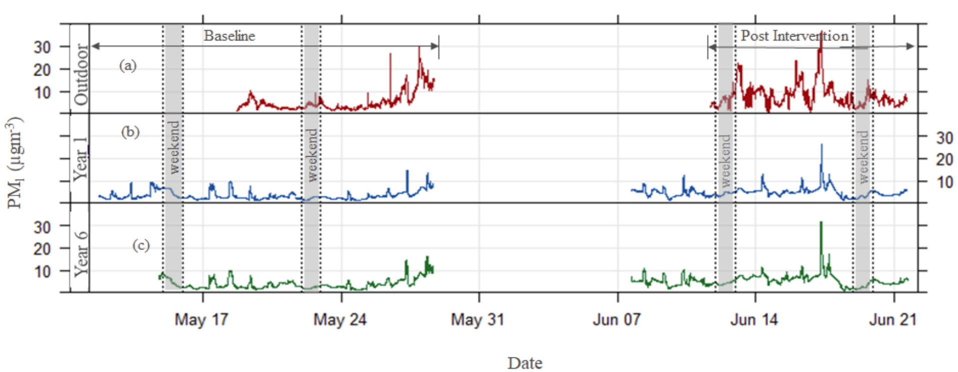

- Outdoor concentrations of all PM generally higher than indoors.
- Inside the classrooms, increases in PM_{10} concentrations occurred during school hours.
- Indoor $PM_{2.5}$ and PM_1 followed variations in outside concentrations.
- Average PM_{10} concentrations were generally within the WHO recommended 24-hour air quality standard for health of 45 µgm^{-3}.
- Average $PM_{2.5}$ concentrations were within the recommended guideline of 15 µgm^{-3}.
- All schools similar PM variations.

Note: The guideline for PM_{10} of 45 µgm^{-3} and for $PM_{2.5}$ of 15 µgm^{-3} are averages for 24-hours, so used here as indicative values only; the averaging times for the measurements carried out in the school were different to that for the guideline value.

School A: Indoor:outdoor Particle Concentrations

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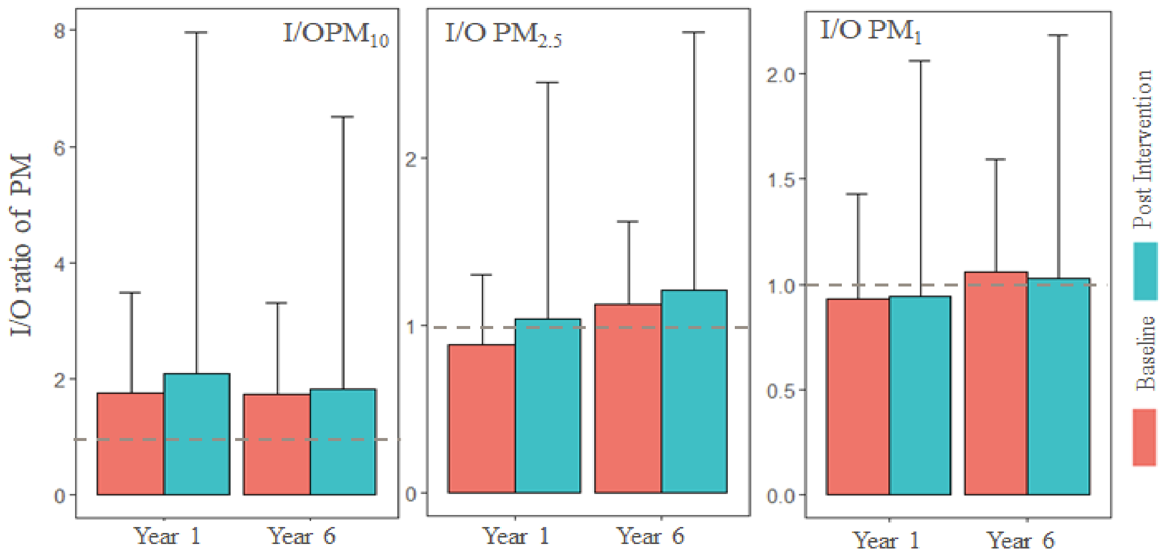

- In general, Indoor:Outdoor (I/O) concentration ratio for PM_{10} was >1.
- PM_{10} generation during school hours were due to teacher/student activities.
- I/O concentration ratios of $PM_{2.5}$ and PM_1 were < 1, during the school hours.
- $PM_{2.5}$ and PM_1 concentrations in classrooms were mainly influenced by outdoor levels, for example, traffic.

School A: Carbon dioxide (CO_2) Concentrations

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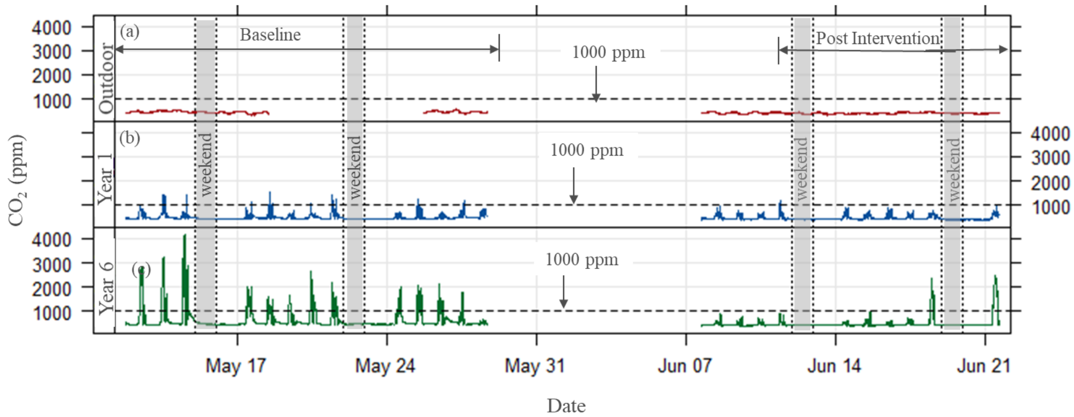
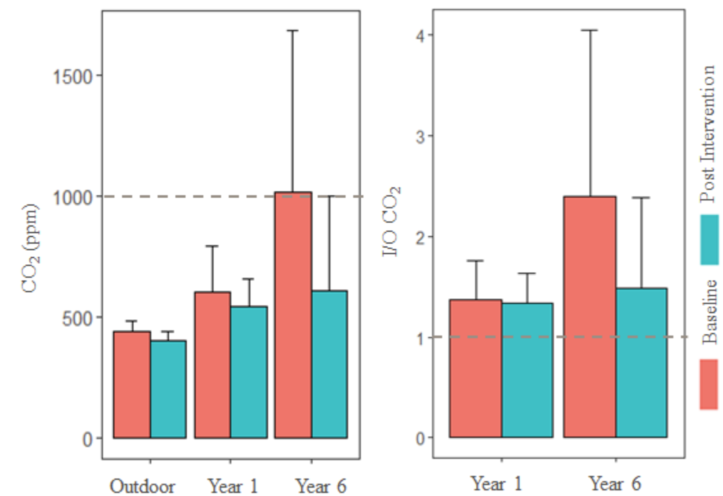




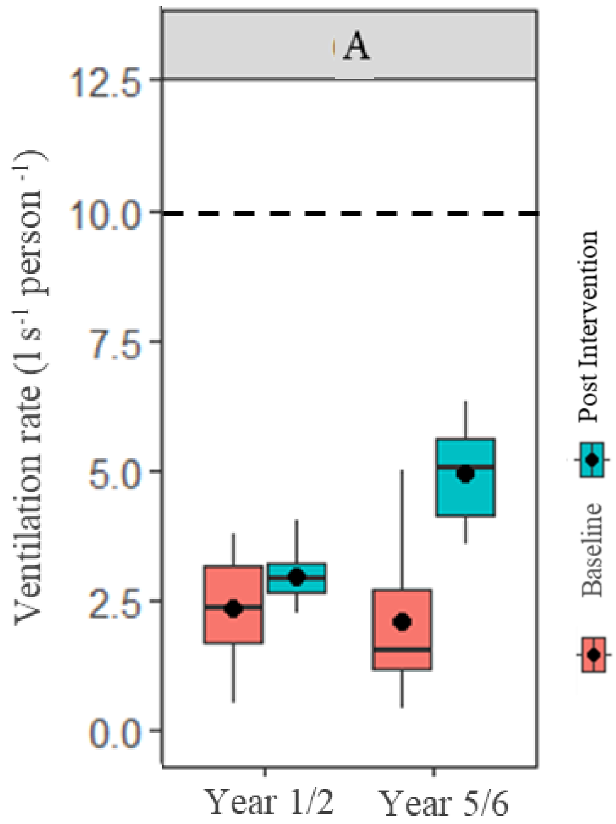
- Outdoor CO_2 concentrations were at typical ambient background levels of around 450 ppm.
- Indoor CO_2 levels varied during the school hours depending upon:
  - The occupancy number, since it is a by-product of human respiration.
  - Ventilation rates.
- I/O concentration ratios of CO_2 rose upto an average value of 3 during school hours across all the schools.

School A: Ventilation

- Ventilation rates in all the classrooms across the schools were below acceptable values recommended by the CIBSE guidelines of 10 l s^{-1} $person^{-1}$.

- Low ventilation rates may have been the cause of elevated CO_2 concentrations due to occupant respiration and PM_{10} concentrations related to occupant activity in the classrooms.

- Important to increase the ventilation rates to reduce indoor CO_2 and PM_{10} concentrations.



School A: Green Screen (GS)

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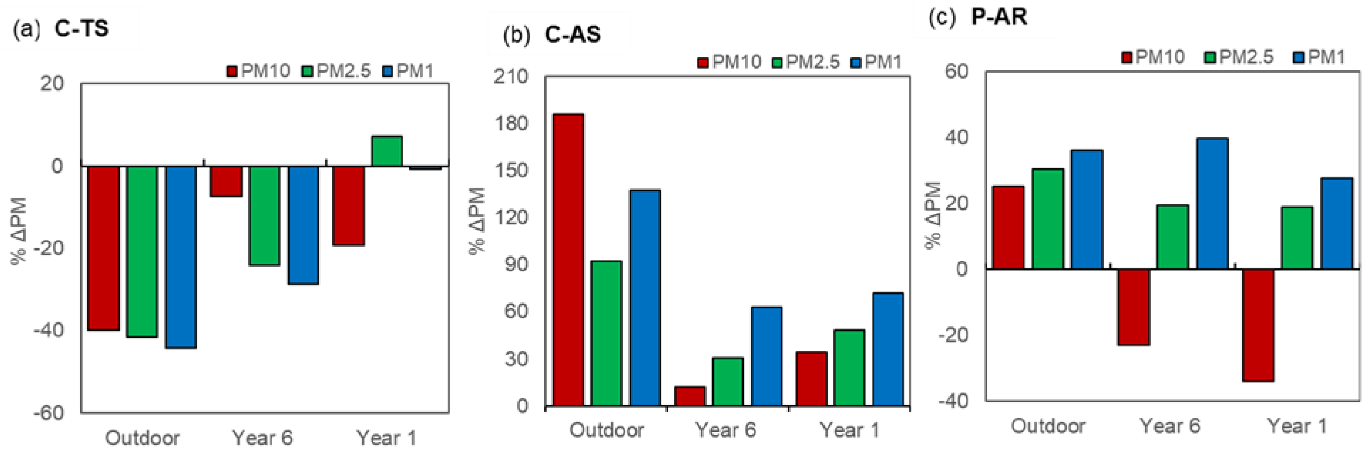

- **Perpendicular winds from road to GS (C-TS):** Reductions in PM_{10} of 40%, $PM_{2.5}$ of 42%, and PM_1 of 44%.
- **Perpendicular winds from school through GS to road (C-AS):** Relatively high PM, trapped due to re-suspension of particles from playground, emissions from neighbouring housing estates and traffic from roads in upwind locations.
- **Parallel winds to GS (P-AR):** Slight increase in PM due to insufficient thickness and density. Green screens are less effective in their early growth stages, since porosity is high due to the leaf area density being low. Fully grown green screens have sufficient thickness to provide an effective barrier for reducing air pollution.
- Green Infrastructure performance to mitigate air pollutants depends on species type, dimensions, density, planting configuration and management (e.g. pruning).

School B: Air Purifier

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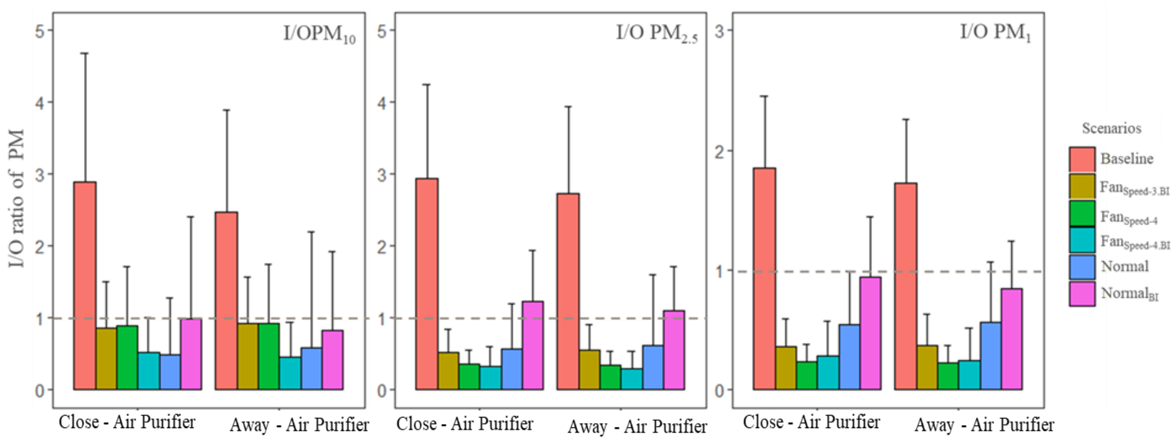
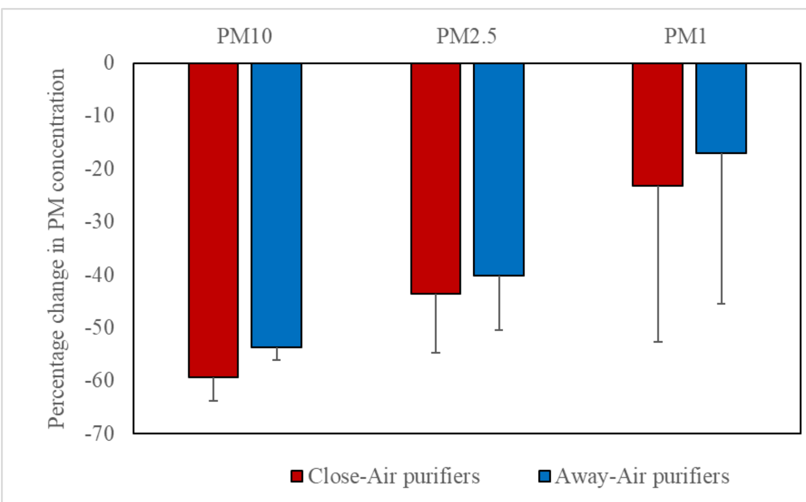
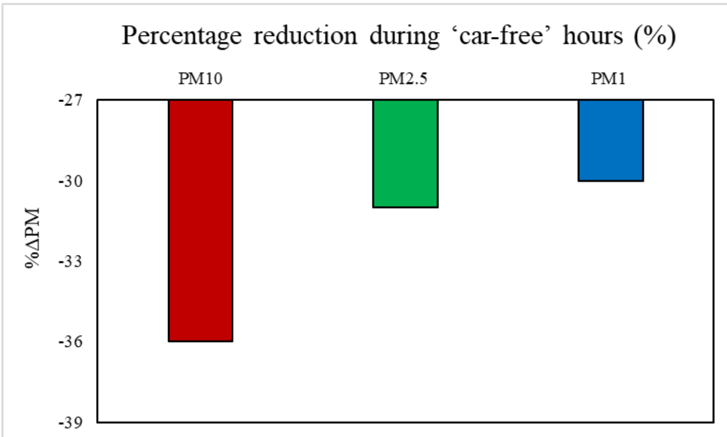




- I/O ratios for all the PM were well below 1 during the various air purifier operating modes, indicating the effectiveness in reducing PM.
- Higher flow rates resulted in larger reductions in PM concentrations.
- Particle reductions:
  - PM_{10} (57%)
  - $PM_{2.5}$ (48%)
  - PM_1 (23%)

School C: School Street



- School street reduced outdoor particle concentrations:
  - PM_{10} (36%) > $PM_{2.5}$ (31%) > PM_1(30%).

- Community based approach is often approximate.
- Further detailed investigations are required to properly quantify and provide scientific evidence of the effectiveness of interventions involving human behaviours: 'walking-bus', 'school-street', minimising 'car idling' with engine running.

Summary of Intervention Assessment Results

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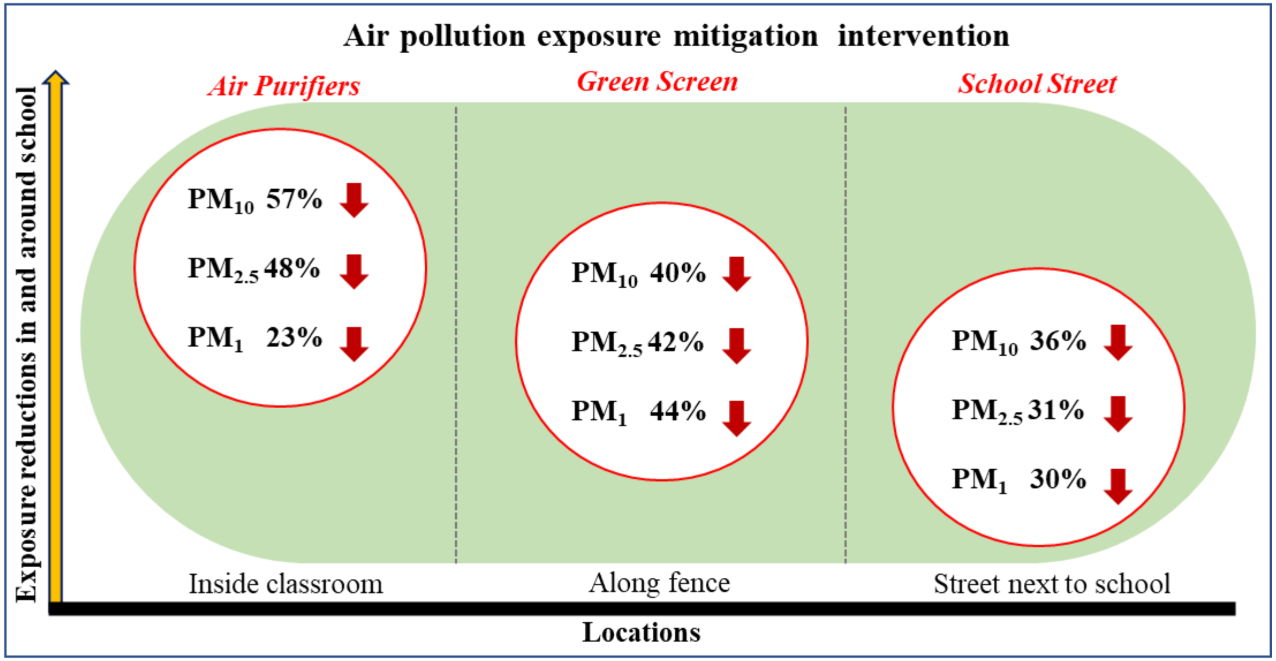
- School A - Green screen at school boundary reduced outdoor particle levels by up to 44%.
- School B - Air purifiers in classroom reduced indoor particle concentrations by up to 57%.
- School C - School street reduced outdoor particle concentrations by up to 36%.



Overall Summary and Conclusions

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- The pilot study investigated the exposure reduction potential of various interventions, such as green screens, air purifiers, and school streets.
- Green screen located at school boundary reduced outdoor particle levels by up to 44%.
- Air purifiers in classroom reduced indoor particle concentrations by up to 57%.
- School street reduced outdoor particle concentrations by up to 36%.
- High levels of CO_2 indoors were due to occupant respiration and inadequate ventilation.
- Effective ventilation is essential to flush out indoor air pollution, including CO_2.

Guidance: Mitigating Exposure to Traffic Pollution In and Around Schools

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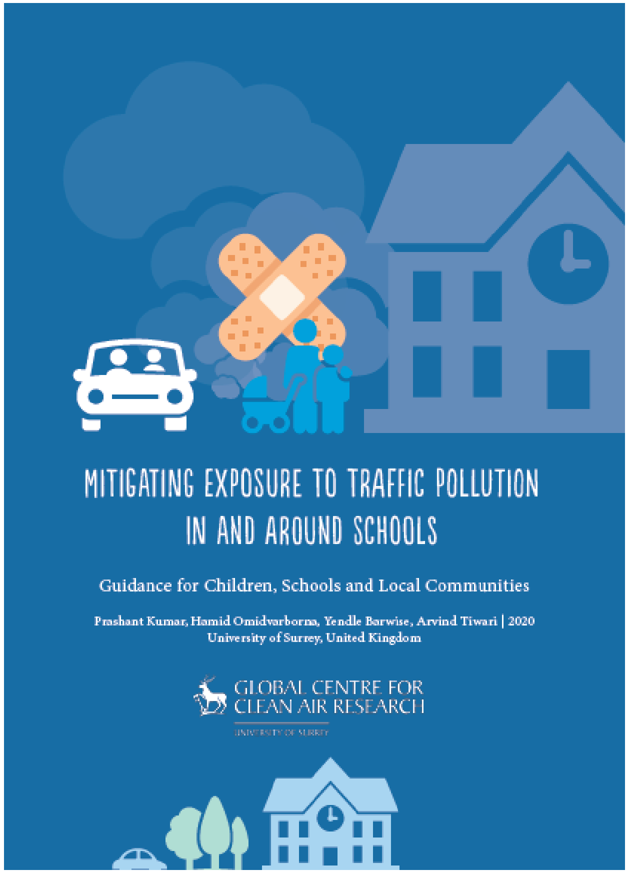
– Simple action points that enable children, schools and local communities to make informed decisions to reduce air pollution exposure in and around the school.

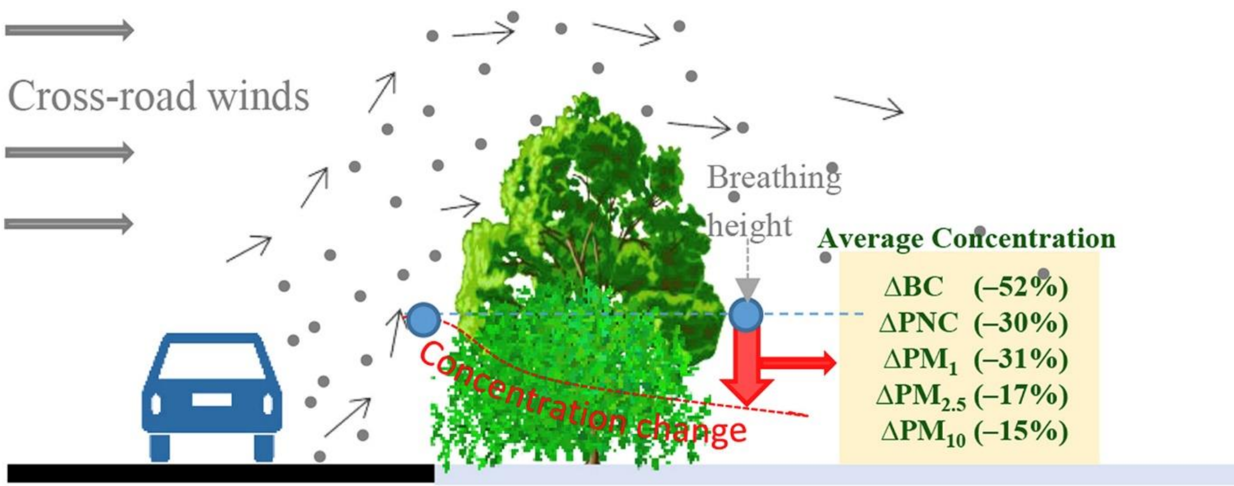
- Avoid non-essential vehicle use.
- Create a clean zone around schools.
- Walk to school.
- Utilise passive control systems, such as green infrastructure (e.g. hedges).
- Consider classroom air quality.
- Include air pollution issues in education.

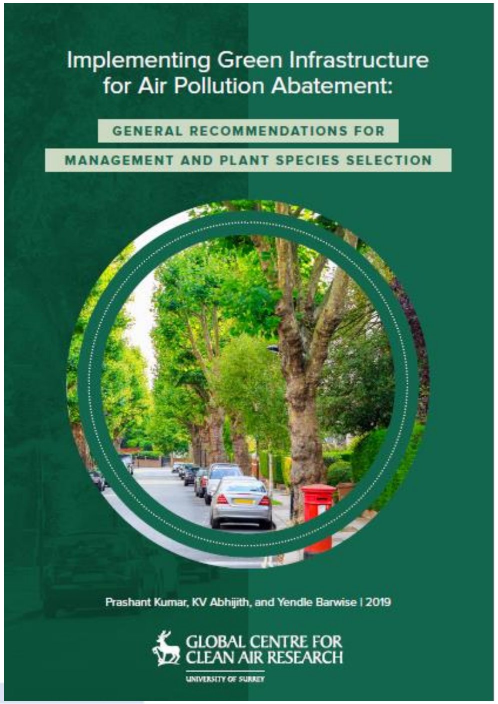


(Kumar et al., 2020)

Air pollution and Green Infrastructure (GI)

- GI includes individual plants and plant-based structures (e.g. green walls, green roofs).
- Vegetation can act as a barrier between pollutant source and receptor.
- Vegetation barrier performance depends on species type, planting configuration and management (e.g. pruning).
- Simple guidance on implementing GI is available.
    - Translated and being used across Europe, China, Brazil, Colombia, India, the Middle East, Africa, Malaysia and others.





(Kumar et al., 2019)

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Many thanks for listening

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