An evidence-based investigation into ventilation and the use of HEPA filters in educational environments

Reported by Dr Henry Burridge; e: <u>h.Burridge@imperial.co.uk</u>, tw: <u>@HenryBurridge</u>

Work carried out be a group of 30+ individuals from 10+ institutions



Air quality & ventilation during the pandemic?

 CIVOS – investigating 'Changes In the Ventilation of Schools' when monitoring CO₂ during 2021 and beyond...

40 <u>naturally ventilated</u> classrooms in 4 schools (2 primary & 2 secondary) Phase 1: Unintrusive monitoring (temperature, RH, CO₂) from the start of 2021

Four schools and 36 classrooms...

Table 1

Information for the schools and classrooms participating in the environmental monitoring study. School names have been anonymised to protect identifying details.

	School ID	No. sensors / Classrooms	Sensor / Classroom ID	Comments	
Primary schools (children aged 4–11 years old)	PA	6	$\{2, 4 \rightarrow 8\}$	Sensors PA-1 and PA-3 were excluded from the analysis due to inconsistent readings and indi- cations that they have been installed in non- classroom environments.	
	PB	8	$\{1 \rightarrow 8\}$		
Secondary schools (children aged 11–18 years old)	SA	8	$\left\{1 \rightarrow 6, 9 \rightarrow 12\right\}$	SA-7 and SA-8 were similarly excluded as the respective rooms saw different usage (a gym ar	
	SB	12	{1→12}	an administrative space) according to the stuc metadata.	

Classroom temperatures in the 4 schools during each study month



○ Cold 1 ○ Transitional 1 ○ Warm 1 ● Warm 2 ● Transitional 2 ● Cold 2

Outdoor temperatures for the 4 schools during each study month



Temperature differences, between classrooms and outdoors, for the 4 schools shown by month



Indoor-outdoor temperature difference:

- Potential to increase ventilation due to increased driving buoyancy force
- Potential to if occupants shut windows due to thermal comfort challenge

Defining the `weather periods'

Date Period	Designation	Tout		
Return to full schooling in March 2021				
08/Mar - 30/April/2021	Cold period 1	7.0°C		
01/May - 28/May/2021	Transitional period 1	10.0°C		
31/May – 23/Jul/2021	Warm period 1	16.5°C		
Summer break between AY	2020-2021 and AY 202	21-2022		
03/Sep - 26/Sep/2021	Warm period 2	15.7°C		
27/Sep - 31/Oct/2021	Transitional period 2	11.9°C		
01/Nov – 17/Dec/2021	Cold period 2	6.8°C		

Why should we care about CO₂ levels?



- Human breath is the dominant source of CO₂ in classrooms
- Ventilation is the dominant mean of diluting CO₂ in classrooms
- CO₂ levels during occupied hours indicates classroom per-person ventilation supply – excess CO₂ (approximately) inversely proportional
- CO₂ levels good general indicator of air quality
- High CO₂ linked to decreases in cogitative function

Classroom CO₂ levels in the 4 schools during each study month

○ Cold 1 ○ Transitional 1 ○ Warm 1 ● Warm 2 ● Transitional 2 ● Cold 2

How much do thermal challenges influence ventilation?



How much do thermal challenges influence ventilation?



Temperature difference, $\overline{\Delta T_{in-out}}$ [^oC]

Classrooms vary even when notionally the same and next door to one another...







(c) PB-3

(d) PB-7

CO₂ concentration, C [ppm Classrooms vary even when notionally the same and next CO₂ concentration, C [ppm] door to one another...

Unoccupied hours



74

Indoor temperature, T_{in} [°C]

(c) PB-3

2500

Unoccupied hours

Indoor temperature, Tin [°C]

(d) PB-7

What can researchers do to help change school air quality in the here and now?

Class-ACT – 'Classroom Air Cleaning Technologies' evidencing the impact of HEPA or UVC filter provision within classrooms

- Environmental monitoring (temperature, RH, CO₂, PMs, VOC) in 330+ classrooms in 30 schools within the Bradford area
- Divided into: 'Control' (no interventions), 'HEPA', and 'UV' schools
- Environmental data analysed for AY 2020/2021
- School attendance data gathered from across the Bradford area

Not for today, this analysis is still ongoing!

We're going to question the impact of HEPA filters on PM and stick to that...

Each 'HEPA classroom' got 3 standalone filter devices. Question impact of: HEPA filters within operational naturally ventilated classrooms

Outdoor temperature in Bradford AY 2021/2022

○ Warm - AU ○ Transitional - AU/WI ● Cold - WI ○ Cold - SP ○ Transitional - SP/SU ● Warm - SU



Date Period	Designation	Date Period	Designation
01/Aug - 30/Sep	Warm – AU	01/Oct – 14/Nov	Transitional – AU/WI
15/Nov – 28/Feb	Cold – WI	01/Mar – 30/Apr	Cold – SP
01/May – 31/May	Transitional – SP/SU	01/Jun – 31/Jul	Warm - SU

Sometimes logical issues can help...

- UV systems not active in schools until Dec/2021
- We neglect UV schools, and treat them as 'Control 2' group until Dec/2021

Study arm	ID	No. Schools	No. Classrooms
CONTROL	С	9	128 (6 to 22 per site)
CONTROL 2	Х	10	95 (6 to 12)
HEPA	Н	11	112 (6 to 14)
Total	-	30	335

Are the (per-person) ventilation levels similar between the groups?



Are the (per-person) ventilation levels similar between the groups?

statistical significance of variations in classroom daily mean CO_2 conc			
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	Intervention	Baseline	$\frac{\Delta \mu}{\mu _{Control}}$
	HEPA	CONTROL	-15%
Warm – AU	HEPA	CONTROL 2	-1%
	CONTROL 2	CONTROL	-14%
	HEPA	CONTROL	-8%
Trans. – AU/WI	HEPA	CONTROL 2	+3%
	CONTROL 2	CONTROL	-11%
Cold – WI	HEPA	CONTROL	+1%
Cold – SP	HEPA	CONTROL	+2%
Trans. – SP/SU	HEPA	CONTROL	-7%
Warm – SU	HEPA	CONTROL	-15%
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Table 2

Differences in mean CO2 levels (infer per-person ventilation levels) are:

<3% between HEPA and Control2 => **always** statistically **insignificant**.

<15% between HEPA and Control => **sometimes** statistically **significant**.

<14% between Control and Control2 => **always** statistically **significant**.

Are the PM levels similar between the groups?



Are the PM levels similar between the groups?

Table 4

Statistical significance of variations in classroom daily mean PM_{10} cor

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	Intervention	Baseline	$\frac{\Delta \mu}{\mu _{Control}}$
	HEPA	CONTROL	-39%
Warm – AU	HEPA	CONTROL 2	-36%
	CONTROL 2	CONTROL	-5%
	HEPA	CONTROL	-49%
Trans. – AU/WI	HEPA	CONTROL 2	-51%
	CONTROL 2	CONTROL	+5%
Cold – WI	HEPA	CONTROL	-47%
Cold – SP	HEPA	CONTROL	-47%
Trans. – SP/SU	HEPA	CONTROL	-47%
Warm – SU	HEPA	CONTROL	-45%

Differences in mean PM levels are: 35-50% between HEPA and Control2 => always statistically significant. 39-49% between HEPA and Control => always statistically significant. <5% between Control and Control2 => always statistically insignificant.

Classroom air quality & ventilation, pandemic + beyond...

- Seasonal variations are consistent, investigation illustrates the thermal comfort needs, and possibly the desire to reduce energy costs, are the most likely causes.
- Significant variations between notionally similar classrooms are consistent highlights further investigation required into:
 - a) school classroom and building variation, and
 - b) the role of the ventilation behaviours of classroom occupants.
- CIVOS Data highlights that in these classrooms (per-person) ventilation rates were significantly lower at the end of 2021 than at the beginning — possible reasons include:
 - a) protocols for UK schools,
 - b) the UK Government's messaging, and
 - c) the populations attitude towards the disease, throughout 2021 are likely contributors to this finding.
- **Class-ACT** highlights that HEPA filters are effective in reducing PM in operational naturally ventilated classrooms, by around 35-50%
- => the crucial link to infection reduction needs to concluded and interpreted in the context of implementation, training and running costs, and all impacts on classroom learning (noise, etc.)