Findings from the academic year 2024/2025 for SAMHE Schools, SAMHE Champions and other interested parties

The SAMHE team

September 2025

1 Executive summary

This report discusses findings from SAMHE data collected during the academic year from September 2024 to June 2025, and we compare findings to those presented in the SAMHE Findings from Autumn term 2024 report (The SAMHE Team, 2024*c*). Data on indoor air quality was recorded from hundreds of SAMHE schools. As in previous academic year, the carbon dioxide (CO_2) levels suggests that keeping classrooms warm during colder weather may, for some schools, provide a significant barrier to providing adequate ventilation. Relative humidity and particulate matter, $PM_{2.5}$, data show that classroom environments are affected by local activities as well as weather and long-range pollution events.

2 Overview of SAMHE

Schools' Air quality Monitoring for Health and Education, SAMHE, was established by the SAMHE project. SAMHE brings together scientists, school pupils, and teachers, to work together to establish a network of air quality monitors in schools across the UK to generate an unparalleled dataset which is providing a better understanding of schools' indoor air quality and its impact. SAMHE has sent monitors to 1 300 schools, and received data from around 750 of these, which are in about 430 schools. Scientists are analysing this data to provide evidence about indoor air quality in UK schools. SAMHE aims to support schools and policy makers to make decisions about how to manage air quality, including through changing ventilation practices, occupancy levels, and about maintaining and improving buildings. The novel methodology of SAMHE (see Chatzidiakou *et al.*, 2023) ensures that all schools (pupils and staff) have access to their raw data through the specially designed Web App (see West *et al.*, 2023, for full details). This both allows scientists to gather valuable contextual data, and acts as a tool for school engagement, including awareness raising and education. We thank all SAMHE schools for making it the success that it has been to date.

3 Forming the SAMHE, and other, datasets for analysis

Most classrooms in the UK are naturally ventilated, where ventilation is managed by classroom occupants (usually staff) opening and closing windows (and sometimes doors or vents). During cooler weather, occupants need to balance having a comfortable room temperature and good ventilation, so we need to know outdoor temperature when trying to understand indoor air quality. We use data provided by the UK's Department for Environment, Food & Rural Affairs which operates the Automatic Urban and Rural Network (AURN). AURN is made up of hundreds of environmental monitoring stations around the UK which provide hourly data for the outdoor temperature and $PM_{2.5}$ concentrations. Each SAMHE school is associated with its closest AURN station to provide an indication of the outdoor temperature and $PM_{2.5}$ concentrations relatively local to each school.

Term dates vary across the UK, so we defined the academic year 2024–2025 as starting on 2^{nd} September 2024 and ending on 26^{th} June 2025. We excluded the following five school holiday periods:

- October half-term: 11^{th} October to 4^{th} November 2024,
- Christmas break: 20^{th} December 2024 to 7^{th} January 2025,
- February half-term: 7^{th} February to 3^{rd} March 2025,
- Easter break: 28^{th} March to 28^{th} April 2025, and
- May half-term: 23^{rd} May to 2^{nd} June 2025.

In addition, any days which were public holidays in any of the four nations of the UK were also defined as non-schooldays and excluded from analysis.

On each school day, the SAMHE dataset was generated by selecting only SAMHE monitors that reported measurements for more than 75% of the time during the school day, i.e. for more than 315 min between 09:00 and 16:00. We used two filters to make sure data was only included from occupied classrooms, which were based on the CO_2 concentrations measured by that school's monitor. First, only data from schools for which the mean CO_2 concentration measured was greater than 480 ppm were included. Second, to ensure we were only including spaces which had classes in them (not, for example, spaces with just a few people in them), we made sure data showed sharp increases in CO_2 concentrations, defined as an increase of at least 100 ppm within any 15-minute period over the school day. On all school days, and for each included school, a mean over the duration between 09:00 and 16:00 was calculated for each metric (this duration enables comparison against Department for Education, 2018); the average of these values are described as the "SAMHE mean temperature", "SAMHE mean humidity", "SAMHE mean CO_2 concentration", and the "SAMHE mean $PM_{2.5}$ concentration" on that day. Doing so provides a dataset of observations of these metrics on 146 days over the academic year — during which time 395 schools contributed to the SAHME dataset. Likewise, on each school day, the 'outdoor daily mean temperature' and 'outdoor daily mean $PM_{2.5}$ concentration' were calculated from the data recorded at the set of AURN stations closest to each 'included school'.

4 Findings from the SAMHE dataset for the academic year 2024–2025

The daily average of outdoor temperatures recorded over the course of the academic year is shown on the graph in figure 1 by the thick green line. Grey horizontal lines indicate the temperature thresholds used to classify the weather for each week into warm periods (above 13°C) (pink-red), intermediate periods (yellow), and cold periods (below 6°C) (blue-lilac) — consistent with previous SAMHE reports (e.g. The SAMHE Team, 2024*d*). The weather period assigned to any week was determined by the maximum number of days, during that week, which fell in any given weather period.

Dotted horizontal lines show the average temperature during each period. We can see that outdoor temperatures, marked by the green line, are warm at the beginning and end of

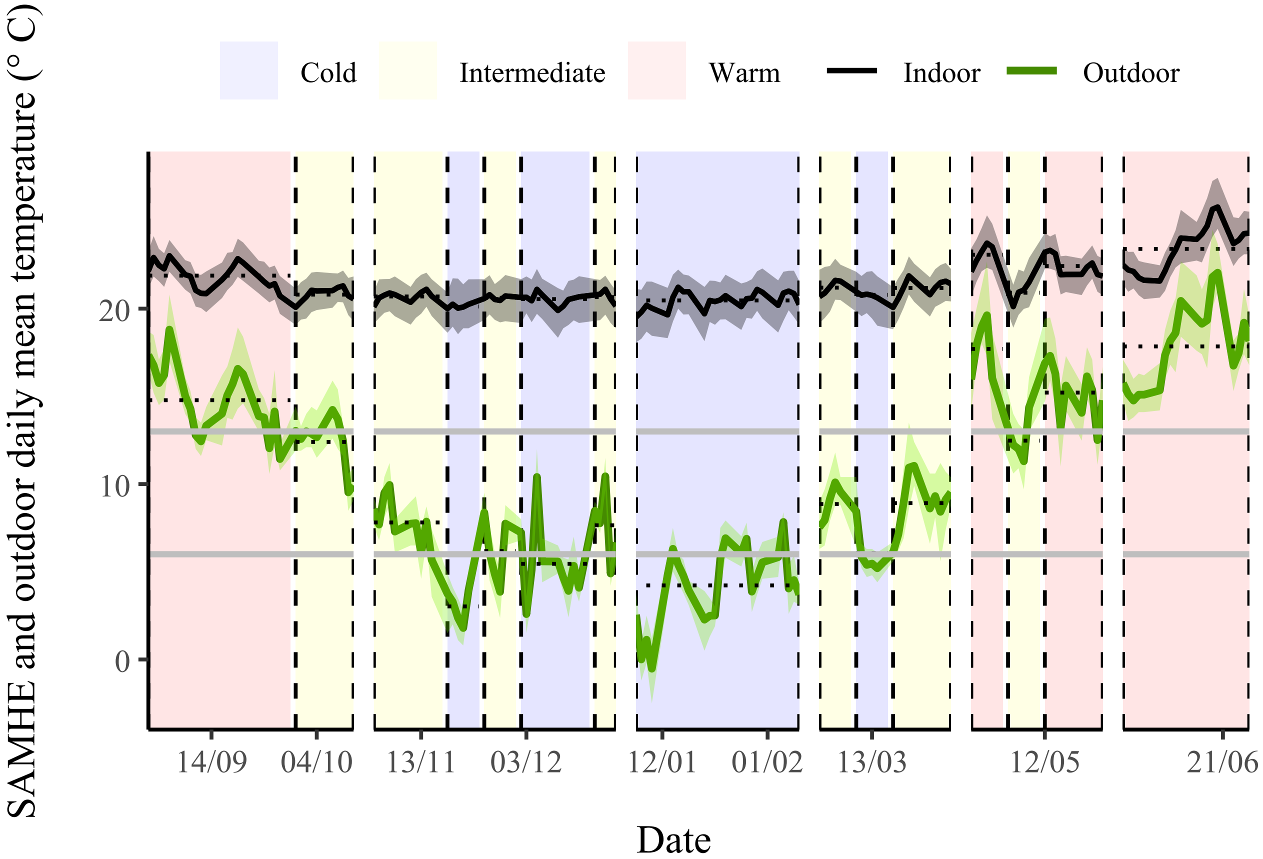

Figure 1: The SAMHE daily mean temperature and the mean outdoor temperature; presented using vertical bands of colour to indicate date periods associated with the warm, intermediate and cold outdoor temperatures — the temperature values of the temperature thresholds are marked by grey horizontal lines. The vertical breaks in data are school holiday periods as detailed above. The grey-shaded and green-shaded areas around the grey and green lines illustrate the interquartile range of the data

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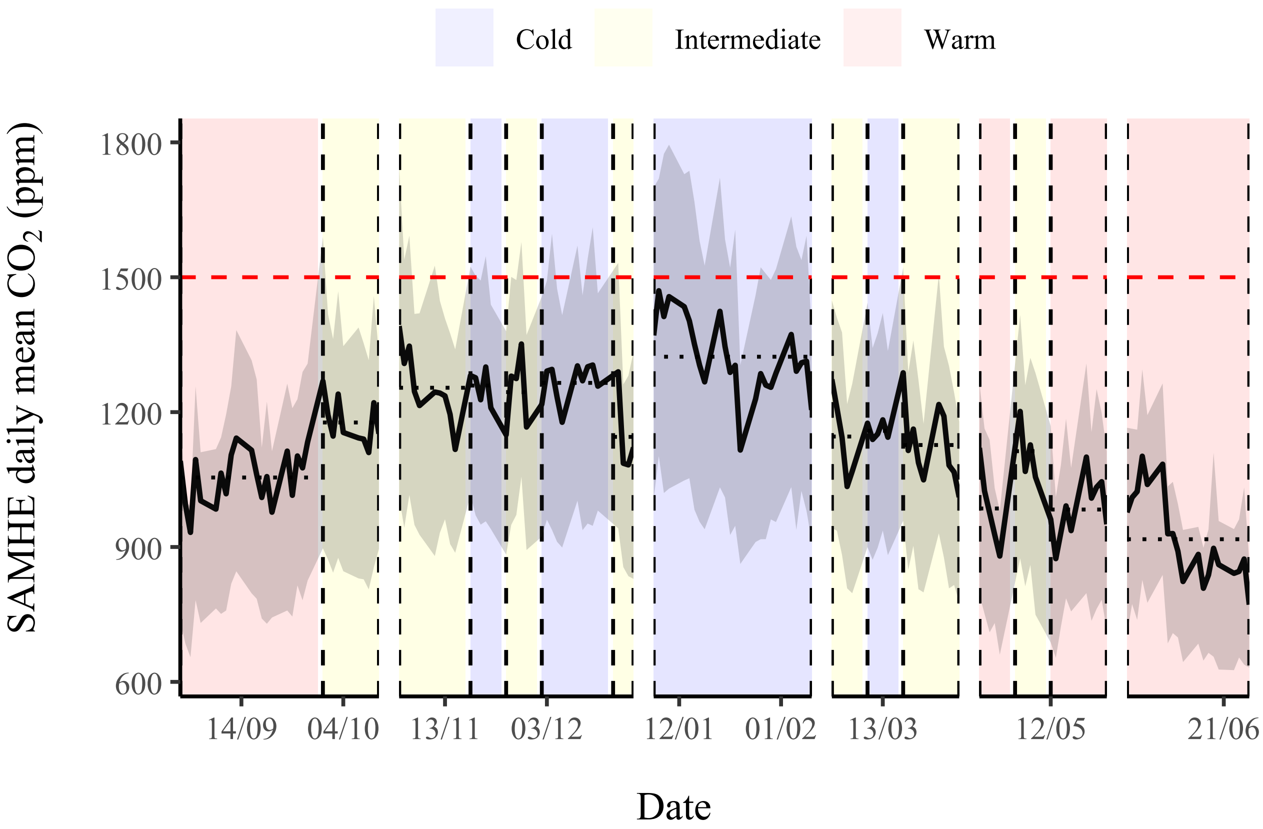

Figure 2: SAMHE daily mean CO_2 concentrations for each school day, with the dotted horizontal lines indicating the mean during each period, and the horizontal dashed red line denoting the BB101 guideline value of 1 500 ppm. The grey-shaded areas illustrate the interquartile range of the data. The vertical breaks in data are school holiday periods as detailed above.

the academic year (pink-red shaded banded area on figure 1). The majority of the year, from October to April, had outdoor temperatures between 0°C and 10°C, with four cold periods (blue bands), two each side of the Christmas break, where the average temperature dropped as low as 0°C. The remainder of the October-April period was classified as intermediate temperature. This is in contrast to the previous academic year 2023–2024 (see The SAMHE Team, 2024*d*) where....

Whilst mean outdoor temperatures vary between about 0°C and 22°C over the year, indoor temperatures recorded by the SAMHE monitors, shown by the black line in figure 1 are fairly consistent throughout the whole year, particularly during the colder months. This indicates schools are able to maintain comfortable indoor temperatures through heating systems. As few schools have air conditioning systems for cooling, indoor temperatures show an upward trajectory from about mid-May until the end of the academic year as outdoor temperatures warm, as in academic year 2023–2024. Overheating in buildings, particularly as a large majority of our schools in the UK are naturally ventilated, is a growing concern as global temperatures continue to rise annually.

Figure 2 shows the daily mean CO_2 concentrations across SAMHE schools over the academic year. These mean CO_2 concentrations provide a good indication of the average per person ventilation supply to classrooms because our exhaled breath is relatively rich in CO_2. The grey-shaded region above and below the black line shows the range in the data, and is broader than those in figure 1, indicating that CO_2 levels varied much more widely between schools than temperature did. Mean CO_2 levels are lower during warmer weather and higher during the cooler winter months. The lower CO_2 concentrations monitored during warmer

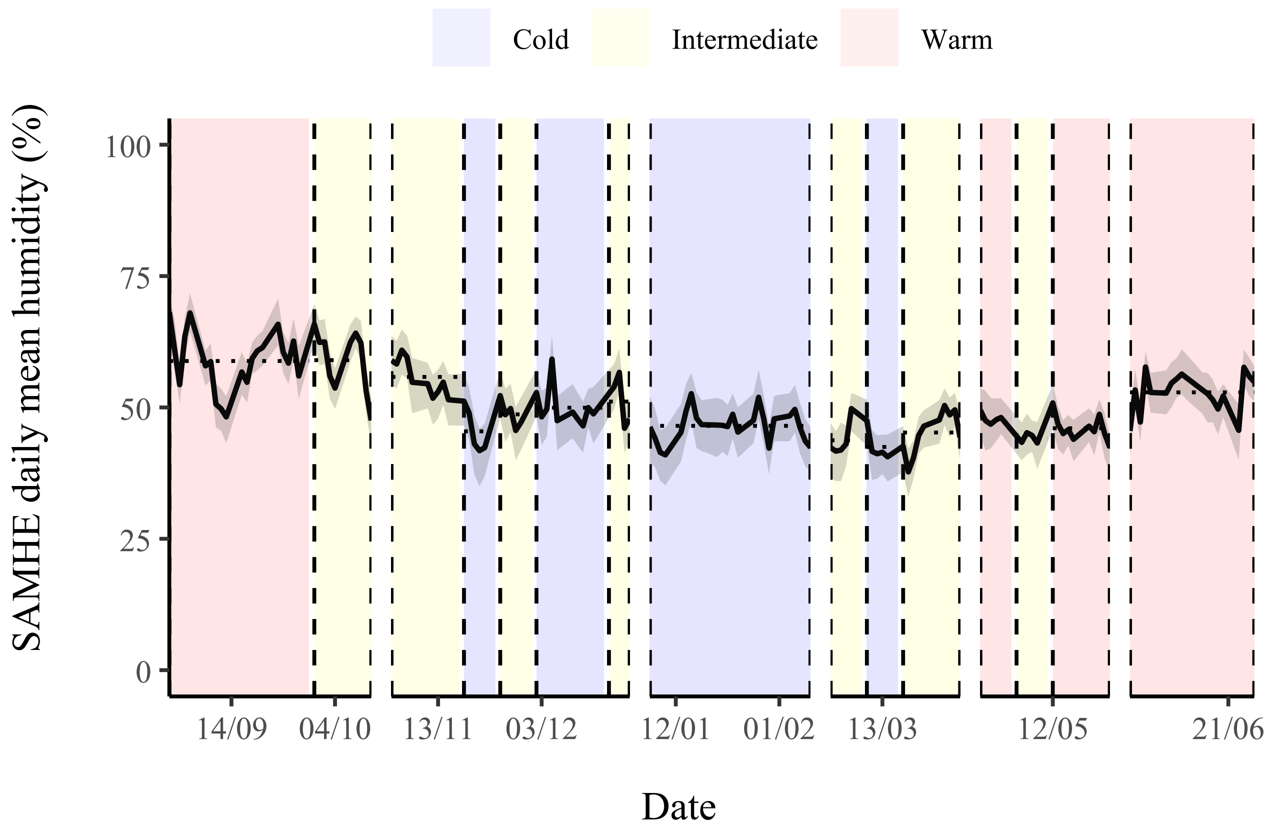

Figure 3: SAMHE daily mean relative humidity for each school day. The horizontal dotted lines show the mean during each weather period, and the grey-shaded areas illustrate the interquartile range of the data. The vertical breaks in data are school holiday periods as detailed above.

weather are likely due to windows being open more often, providing better ventilation. During the colder periods (shown in blue on figure 2), mean daily CO_2 levels are elevated, suggesting windows remain closed to retain heat in the classrooms. Government guidance (Department for Education, 2018) for naturally ventilated classrooms suggests that daily average CO_2 concentrations should not exceed 1 500 ppm and this level is indicated by the red dashed line in figure 2. During the cooler periods, over 25% of the SAMHE monitors were measuring CO_2 levels above this daily threshold (shown by the grey shaded region above the dashed red line). This suggests that trying to keep classrooms warm during colder weather is a barrier to providing adequate ventilation. The CO_2 data from 2024–2025 is consistent with that from the previous academic year (see The SAMHE Team, 2024*d*), highlighting that these challenges are faced by schools each year. For some schools, education and training of classroom staff regarding ventilation behaviours might mitigate this, whereas for others, the architecture, building services, maintenance of the school estates, or other factors, may be a more significant barrier. SAMHE schools have access to their own data through the SAMHE Web App and are guided through activities which can help them determine what action can be taken to improve ventilation; it is possible that ventilation may be worse in schools which are less aware of the importance of air quality within their school.

Mean CO_2 concentrations provide an indication of the per person ventilation supply to classrooms because our exhaled breath is relatively rich in CO_2. Our breath is also rich in moisture and hence contributes to humidity. Figure 3 shows the relative humidity data from the SAMHE monitors. The trends in relative humidity over the weather periods are generally the opposite of those in the CO_2 data. Whilst CO_2 concentrations of outdoor air vary relatively

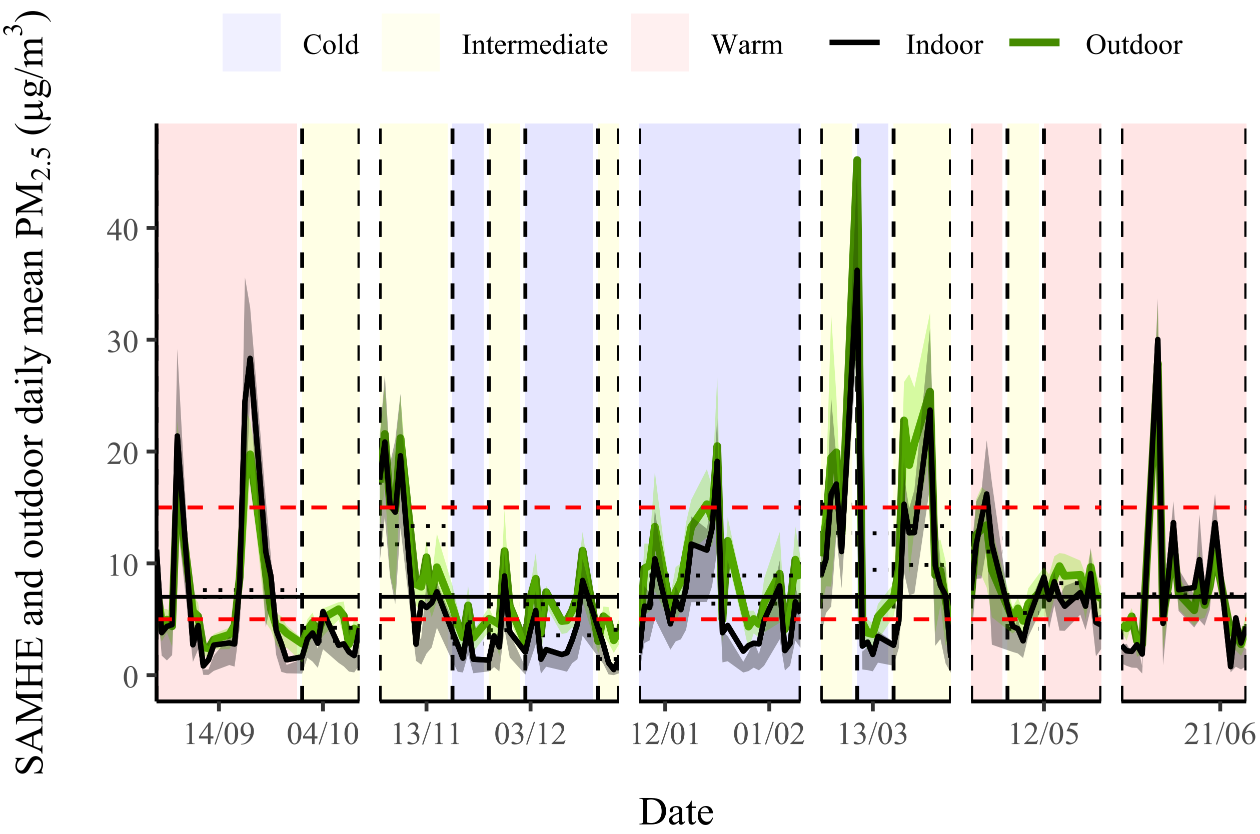

Figure 4: SAMHE daily mean $PM_{2.5}$ concentrations over the year, marked by the black line, and those measured outdoors, marked by the green line. Dotted horizontal lines indicate the mean during each period, and the horizontal dashed red lines denotes the guidance values of $5\,\mu g/m^3$ and $15\,\mu g/m^3$, recommended by the World Health Organisation for annual and daily concentration limits. The appropriately coloured shaded areas around each line illustrates the interquartile range of the data. The vertical breaks in data are school holiday periods as detailed above.

little over the course of one school term, relative humidity in the outdoor air does vary with the weather, typically becoming drier (lower humidity) during colder weather. Figure 3 suggests that relative humidity levels in classrooms are influenced mainly by the weather, rather than by occupants breathing.

Figure 4 shows the $PM_{2.5}$ concentrations measured indoors by the SAMHE monitors and outdoor $PM_{2.5}$ data from the AURN (see section 3 above and Defra AURN, 2024). From figure 4 we can see that rises and falls in the $PM_{2.5}$ concentrations measured indoors by the SAMHE monitors (shown by the black line) largely follow the rises and falls of the $PM_{2.5}$ data measured outdoors (shown by the green line). Again, this is consistent with the findings based on the previous academic year (The SAMHE Team, 2024*d*), reinforcing the consistency in the data being gathered.

Figure 4 shows there were 8 periods where the $PM_{2.5}$ concentrations across SAMHE schools spiked above $15\,\mu g/m^3$ — a value which the World Health Organisation's air quality guidelines state 24-hour mean $PM_{2.5}$ concentration should not exceed (World Health Organization, 2023). The World Health Organisation also has a guideline value for annual mean $PM_{2.5}$ concentration of $5\,\mu g/m^3$ (shown in the figure as the lower red dotted line), and the average for SAMHE schools over the academic year was higher than this, at $7.0\,\mu g/m^3$ (shown by the solid black line). The average last year was $4.6\,\mu g/m^3$. Table 1 summarises the data for academic years 2023–2024 and 2024–2025. This summary shows that the $PM_{2.5}$ concentrations both indoors and outdoors increased between the two years (an increase of $2.4\,\mu g/m^3$indoors and

		Mean	Median	Standard Deviation
2023-2024 (Number of schools = 442)	Outdoor temp, °C	10.7	9.9	5.6
	SAMHE temp, °C	21.5	21.2	1.3
	CO_2, ppm	1010	1020	160
	Outdoor $PM_{2.5}$, $\mu g/m^3$	6.6	5.5	4.0
	SAMHE $PM_{2.5}$, $\mu g/m^3$	4.6	2.8	4.9
2024-2025 (Number of schools = 395)	Outdoor temp, °C	10.4	9.6	5.4
	SAMHE temp, °C	21.4	21.0	1.2
	CO_2, ppm	1140	1140	150
	Outdoor $PM_{2.5}$, $\mu g/m^3$	8.4	6.5	6.0
	SAMHE $PM_{2.5}$, $\mu g/m^3$	7.0	4.7	6.2

Table 1: Table of the summary statistics, averaged over a full academic year, of the mean outdoor temperatures, and the mean temperatures, CO_2, and $PM_{2.5}$ measured by the SAMHE monitors. Data for the academic years 2023–2024 and 2024–2025 are shown.

$1.8\,\mu g/m^3$ outdoors). This suggests that a large proportion of the increase in concentrations measured inside schools could be coming from outdoors, emphasising the importance of supporting improvements in outdoor air quality alongside improving management of indoor school environments.

4.1 Highlights from SAMHE findings to date, and summary statistics by academic year

The school environment and air quality data, and other data, contributed by SAMHE schools is giving new insight into classroom air quality. Key findings from the work so far, and links to the full-text publications, can be found below:

- In September 2023, dust from Africa's Sahara desert was blown to the UK. SAMHE data showed that this dust was affecting the air quality in UK classrooms, showing that pollutants can travel around the globe (The SAMHE Team, 2024*b*).
- Measurement of how much fresh air enters a room, or the 'ventilation rate' is key to understanding how air pollution gets in and out. The SAMHE Team developed a new method to estimate the ventilation rate from carbon dioxide, CO_2, measurements, and allowed us to show that ventilation rates in primary and secondary schools are similar, even though CO_2 levels were higher in secondary schools because older children breathe out more CO_2 (Finneran & Burridge, 2024).
- During autumn in the UK, fireworks are used to celebrate Diwali and Bonfire night. These release pollutants, including particulate matter $PM_{2.5}$ which the SAMHE monitors detected inside classrooms, despite the firework events occurring outside of school hours. Fortunately, the raised $PM_{2.5}$ concentrations had largely dropped again by the start of the next school day, but the finding highlights that $PM_{2.5}$ pollution can still enter UK school classrooms even when schools are closed. The finding that $PM_{2.5}$ was still entering schools when they were closed has implications for school energy efficiency because whenever $PM_{2.5}$ was still able to enter schools, heat can also be leaking out (The SAMHE Team, 2024*a*).
- Particulate matter concentrations in classrooms are closely linked to concentrations outdoors, with most of the $PM_{2.5}$ pollution within classrooms comes from polluted outdoor air entering buildings. This shows how important it is to improve air quality in the UK

and suggests that improving school air quality (for example, by monitoring air quality, and better management of school ventilation or air filters) could play a role in reducing children's exposure to harmful air pollutants (Handy *et al.*, 2025).

- Mirroring what we have shown in this report, analysis of the first full term of CO_2 measurements from SAMHE monitors showed many schools struggle to maintain adequate ventilation during colder weather. Worse ventilation was generally found in schools in poorer areas, and schools where they had more pupils than their target number of pupils. (Wood *et al.*, 2024).

The data from SAMHE schools is being used by the SAME team to make recommendations for changes in policy and practice that could be expected to improve the air quality and environments in schools - you can download and share our recommendations from https://samhe.org.uk/recommendations.

5 Acknowledgements

The SAMHE team would like to thank all of the schools, teachers and pupils who have participated in SAMHE project and acknowledges the contribution of everyone involved, including former members of the SAMHE team, the SAMHE Steering Committee and SAMHE Engagement Panel, for their support and guidance.

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