Findings from the academic year 2023/2024 for SAMHE Schools, SAMHE Champions and other interested parties

The SAMHE project team

August 2024

1 Executive summary

This report discusses findings from SAMHE data collected during the academic year from September 2023 to June 2024. Data on indoor air quality was recorded from hundreds of SAMHE schools over the course of the year. All findings reported here are based on averages across all of those schools. As previously reported, analysis of the data on carbon dioxide (CO_2) levels suggests that keeping classrooms warm during colder weather periods may, for some schools, provide a significant barrier to providing adequate ventilation. Both the relative humidity and particulate matter $PM_{2.5}$ data indicate that the classroom environments are not only affected by conditions local to the school but are also influenced by weather and long-range events.

2 Overview of SAMHE

The Schools' Air quality Monitoring for Health and Education (SAMHE) Initiative was established by the SAMHE project. The Initiative brings together scientists, school pupils, and teachers, to work together to establish a network of air quality monitors in schools across the UK in order to generate an unparalleled dataset which will provide a better understanding of schools indoor air quality and its impact. The initiative gives air quality monitors to schools which agree to take part in the research. It has deployed monitors to over 1 300 schools and, as of July 2024, receives data from around 750 of the monitors deployed in about 430 schools. This data is being analysed by scientists to provide evidence about indoor air quality in UK schools. The aim is to support schools and policy makers in decisions, both about the UK school estate and its maintenance and improvement, and also the management of air quality through other means, such as changes in occupancy levels and the use of ventilation. The novel methodology of SAMHE (see Chatzidiakou *et al.*, 2023) ensures that all schools have access to both the raw data from their SAMHE monitor and to the project findings. Data generated by each SAMHE school is made available to staff and pupils through a specially designed Web App (see West *et al.*, 2023, for full details). This acts as a tool for school engagement, including awareness raising and education, and also as a means to gather valuable contextual data for the project.

3 Findings from the SAMHE data for the academic year 2023/2024

Most classrooms in the UK are naturally ventilated. The level of ventilation is managed by classroom occupants (usually staff) opening and closing windows (and sometimes doors or vents). During cooler weather they are likely to try to strike a balance between achieving a comfortable room temperature and good ventilation, so when we try to understand indoor air quality, we need to account for outdoor temperature. We use data from the UK Met Office dataset 'MIDAS' as a record of the outdoor temperatures local to each SAMHE school. Dates were defined for the academic year 2023/2024 to account for variability in school term dates across the UK, starting from 5^{th} September 2023 and ending on 26^{th} June 2024, herein to be referred to as the "academic year". The 5 school holiday periods for this academic year are defined as follows:

- October half-term: 14^{th} October to 5^{th} November 2023
- Christmas break: 16^{th} December 2023 to 8^{th} January 2024
- February half-term: 10^{th} February to 25^{th} February 2024
- Easter break: 23^{rd} March to 14^{th} April 2024
- May half-term: 4^{th} May to 2^{nd} June 2024

The number of schools engaging with SAMHE increased over the academic year 2023/2024 and so the set of monitors included within the dataset analysed grew each term to reflect this. In each term, only SAMHE monitors reporting data (for at least 75% of the school day) on at least 30 school days during the term were included. Monitors from the following number of schools were included in the analysis of each term: 302 schools in the Autumn term, 366 in the Spring term, and 417 schools in the Summer term. The daily average of outdoor temperatures recorded over the course of the academic year is plotted in figure 1 and shown on the graph as a green line. Throughout this report 'daily average' values refer to the mean of values measured during occupied 'school hours', defined as between 09:00 to 16:00 on school days only, as per (which enables comparison against Department for Education, 2018). Dashed horizontal lines indicate the temperature thresholds that we have used to classify the weather into a warm periods (above 13°C), intermediate periods, and cold periods (below 6°C)— consistent with previous SAMHE reports (The SAMHE Project Team, 2024a,b, see: SAMHE Findings from Autumn term 2023 report, SAMHE Findings from Spring term 2024 report). Throughout our analysis, we highlight data associated with warmer outdoor temperatures using a pink-red background, intermediate outdoor temperatures with a yellow background and cold outdoor temperatures using a blue-lilac background.

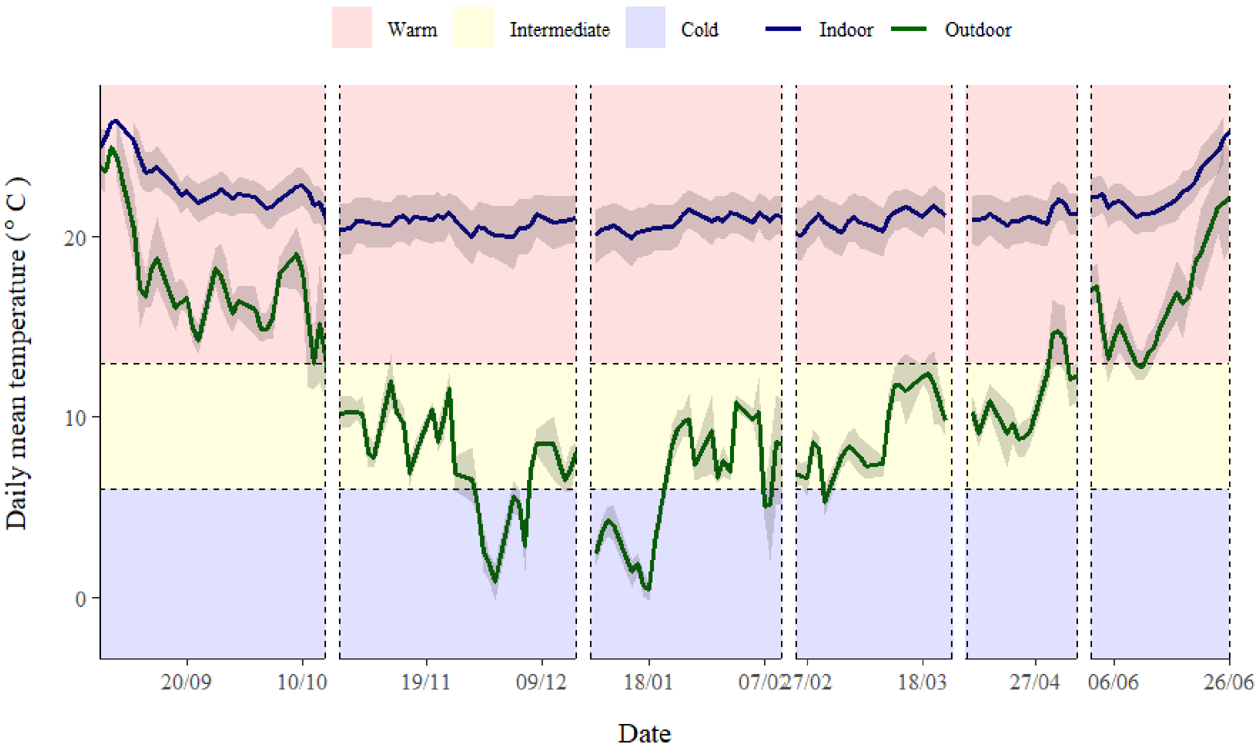

Figure 1: Daily mean temperature within SAMHE schools (marked by the green line) and outdoors (marked by the blue line). Horizontal bands of colour indicate the outdoor temperature ranges deemed to be cold, intermediate, and warm. The grey-shaded areas, above and below the means, illustrate the interquartile range of the data. The vertical breaks in data are school holiday periods, as detailed above.

Figure 2 highlights various weather periods over the course of the academic year as classified by the outdoor temperature ranges identified in figure 1. These periods are indicated using vertically banded colours. The white horizontal bands indicate school holidays occurring during the academic year as detailed above. Dashed horizontal lines show the average temperature during each period. We can see that outdoor temperatures are warm at the beginning and end of the academic year (red banded area on figure 2). A large proportion of the term from October to April sees temperatures fluctuating around 10°C (yellow banded areas on figure 2) with 2 cold periods either side of the Christmas break where temperatures dropped down to 0°C (blue banded areas on figure 2). By contrast, the temperatures recorded by the SAMHE monitors — labelled "indoor" and marked by the blue line in figures 1 and 2 — remain fairly consistent throughout the whole year, particularly during the colder months. This trend showing relatively consistent and comfortable indoor temperatures throughout the year is presumably due to heating being turned on during the colder months. It should be noted that indoor temperatures show an upward trajectory at the start and end of the data period as outside temperatures reach above 23°C. 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.

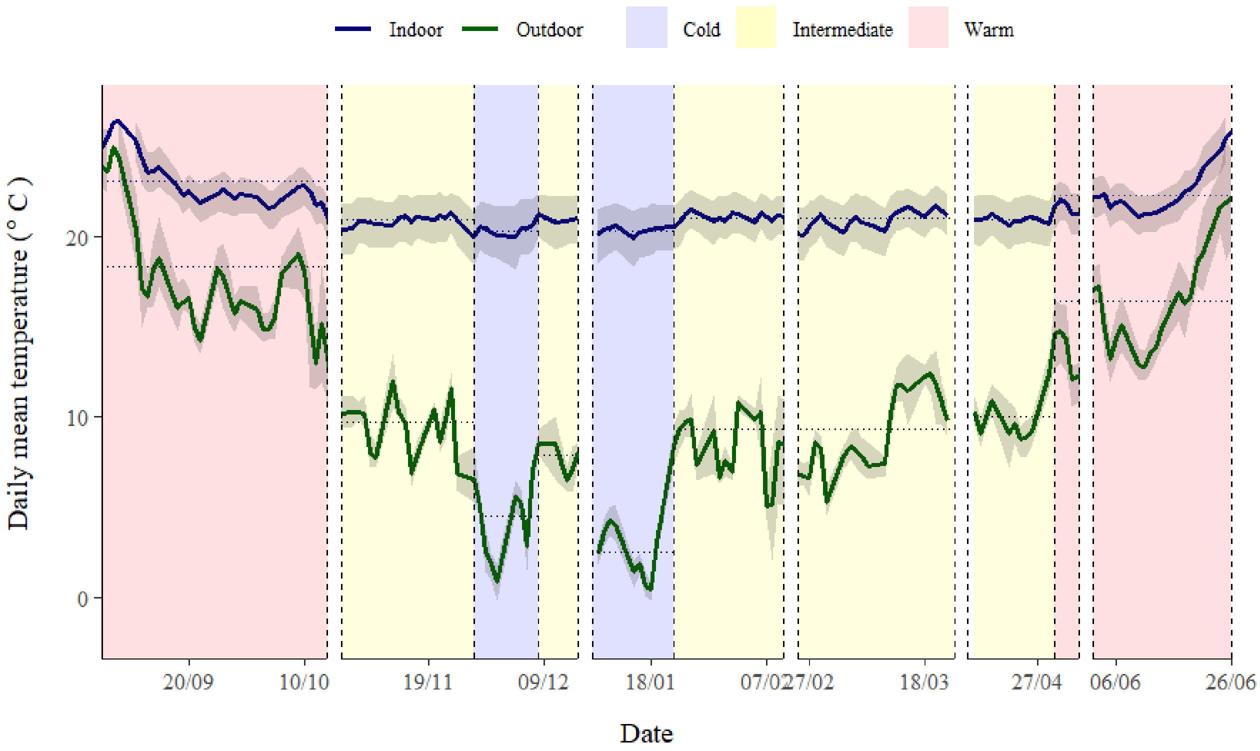

Figure 2: The same daily mean temperature data as was plotted in figure 1; however, here presented using vertical bands of colour to indicate date periods associated with the warm, intermediate and cold outdoor temperatures. The vertical breaks in data are school holiday periods as detailed above.

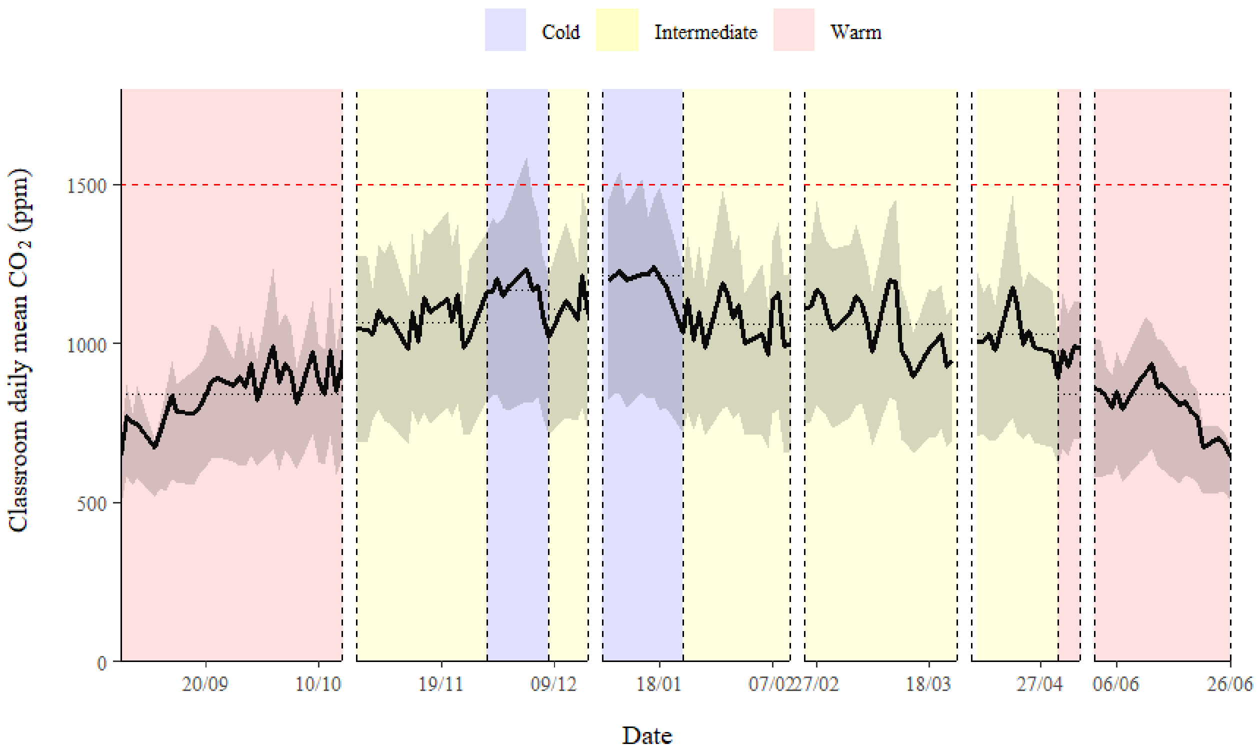

Figure 3: Daily mean CO_2 concentrations for each school day, with the dotted horizontal lines indicating the mean during each period, and the horizontal dashed red line denoting the BB101 guideline value of 1 500 ppm. The grey-shaded areas illustrate the interquartile range of the data. The vertical breaks in data are school holiday periods as detailed above.

Figure 3 shows the daily mean CO_2 concentrations across SAMHE schools over the academic year. The mean CO_2 concentrations provide a good indication of the average per person ventilation supply to classrooms. The grey-shaded areas are much broader than those in figure 2, indicating that CO_2 levels measured by the SAMHE monitors varied much more widely between schools than the variation seen with classroom temperature. There is an obvious trend in the mean CO_2 levels showing lower concentrations of CO_2 during warmer weather and increasing concentrations during the cooler winter months. The lower CO_2 concentrations monitored during warmer weather are likely due to windows being open more often, providing better ventilation.

During the colder periods (shown by the blue shaded areas on figure 3), mean daily CO_2 levels are elevated. The increased mean CO_2 levels when outside temperatures were cold strengthens the presumption that windows remain shut 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 3. During the cooler period, a proportion of classrooms exceeded this daily threshold, suggesting that trying to keep classrooms warm during colder weather is a barrier to providing adequate ventilation (see also The SAMHE Project Team, 2024*a*)). 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. 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.

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. Our breath is also rich in moisture and hence contributes to humidity. Figure 4 shows the relative humidity data gathered by 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 in the outdoor air vary relatively little over the course of one school term, relative humidity in the outdoor air does vary with the weather, typically becoming drier, i.e. lower humidity, during colder weather. Figure 4 suggests that humidity levels in classrooms are influenced mainly by the weather, rather than by occupants breathing.

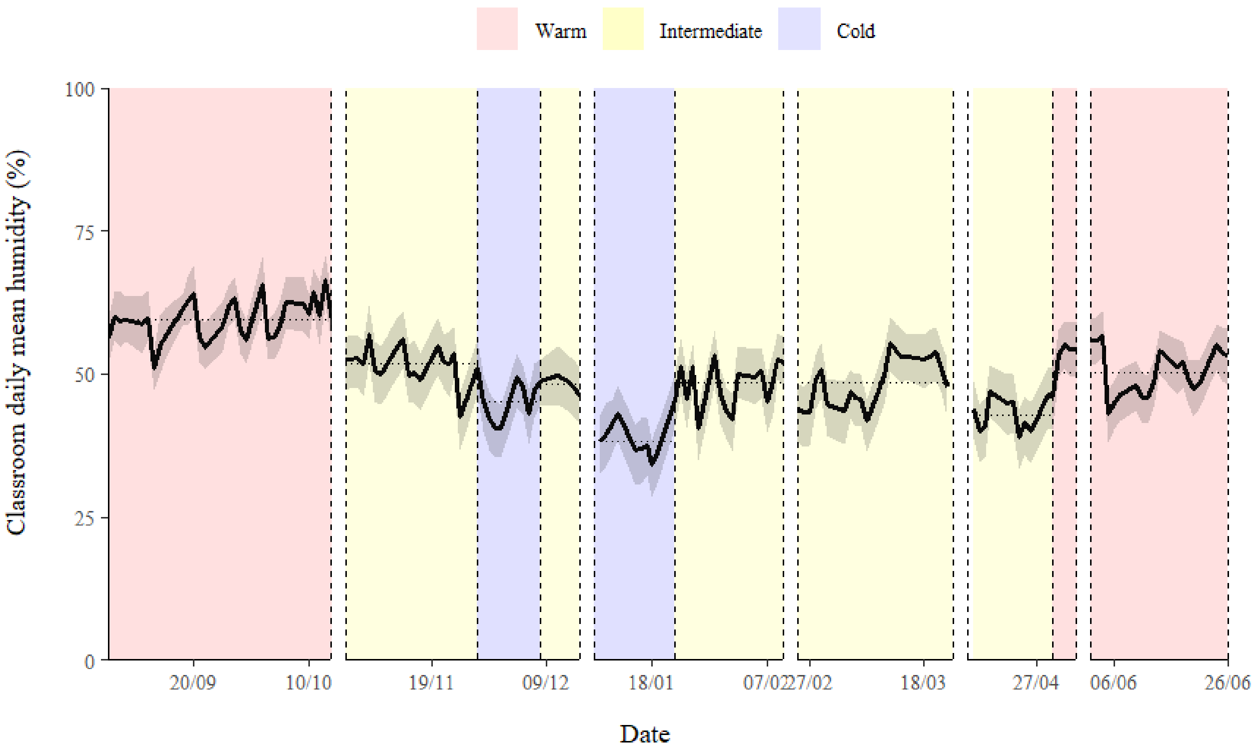

Figure 4: Daily mean relative humidity for each school day. The horizontal dotted lines show the mean during each weather period, and the grey-shaded areas illustrate the interquartile range of the data. The vertical breaks in data are school holiday periods as detailed above.

The SAMHE monitors also measure $PM_{2.5}$. Figure 5 shows the period mean $PM_{2.5}$ concentrations measured by the SAMHE monitors, which all lie reassuringly below the maximum daily mean value of 15 $\mu g/m^3$ recommended by the World Health Organisation (World Health Organization, 2023). There is no consistent variation in the measured $PM_{2.5}$ concentrations with outdoor temperature, with the averages during the cold, intermediate, and warm periods fluctuating between 2-6 $\mu g/m^3$. This indicates that outdoor temperature does not significantly affect the $PM_{2.5}$ concentrations in these SAMHE schools.

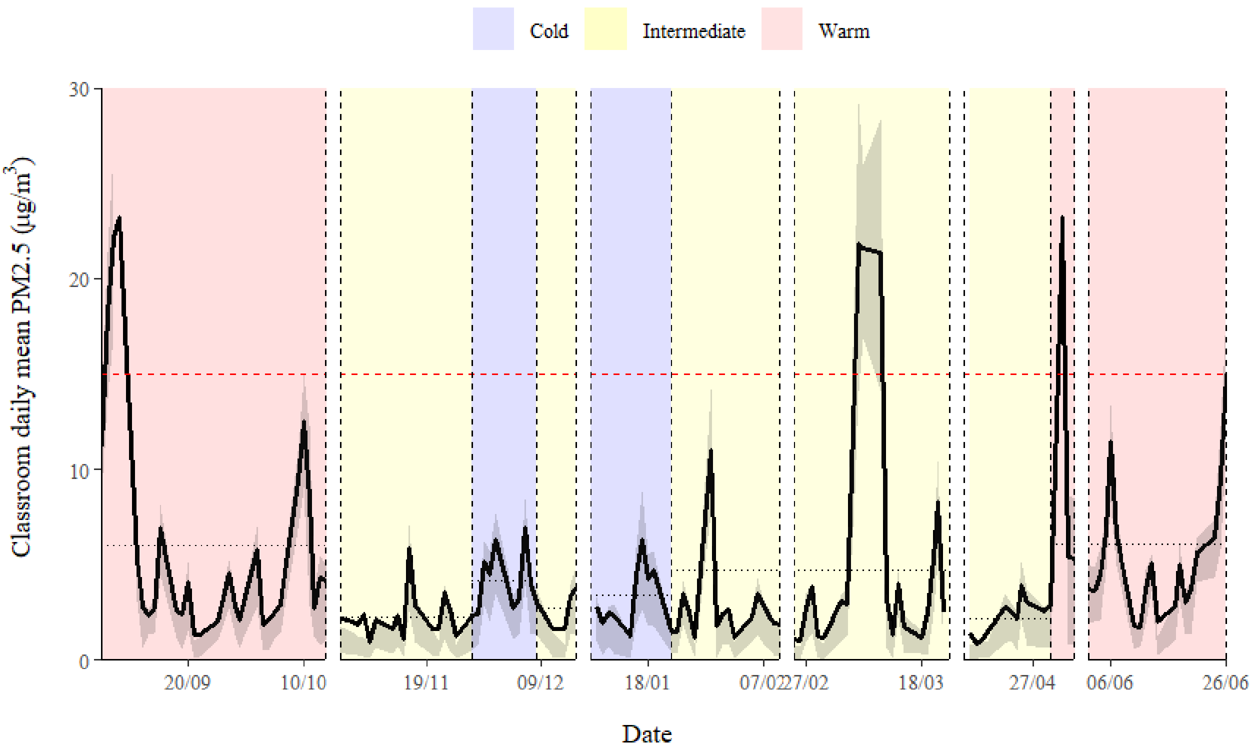

Figure 5: Daily mean $PM_{2.5}$ concentrations for each school day, with the dotted horizontal lines indicating the mean during each period, and the horizontal dashed red line denoting the maximum daily mean value of $15\,\mu g/m^3$ $PM_{2.5}$ recommended by the World Health Organisation. The grey-shaded areas illustrate the interquartile range of the data. The vertical breaks in data are school holiday periods as detailed above.

There were 3 significant spikes in $PM_{2.5}$ seen across SAMHE schools, when mean concentrations levels were greater than $20\,\mu g/m^3$. Figure 6 shows the $PM_{2.5}$ concentrations measured indoors by the SAMHE monitors and includes outdoor $PM_{2.5}$ data measured across the Government's national monitoring network (AURN, Automatic Urban and Rural Network), which is the UK's main network for monitoring air quality (Defra AURN, 2024). From figure 6 we can see that rises and falls in the $PM_{2.5}$ concentrations measured indoors by the SAMHE monitors (shown by the blue line) largely follow the rises and falls of the $PM_{2.5}$ data measured outdoors (shown by the green line). This reinforces our previously reported finding that $PM_{2.5}$ levels in classrooms are influenced not only by activities inside, and local to, schools but also by regional and national $PM_{2.5}$ concentrations (The SAMHE Project Team, 2024*a*). Since long-term exposure to elevated $PM_{2.5}$ concentrations is linked with negative health outcomes (Public Health England, 2018), SAMHE is keen to evidence the scale of these exposures in classrooms and contribute to understanding their sources and potential mitigation measures.

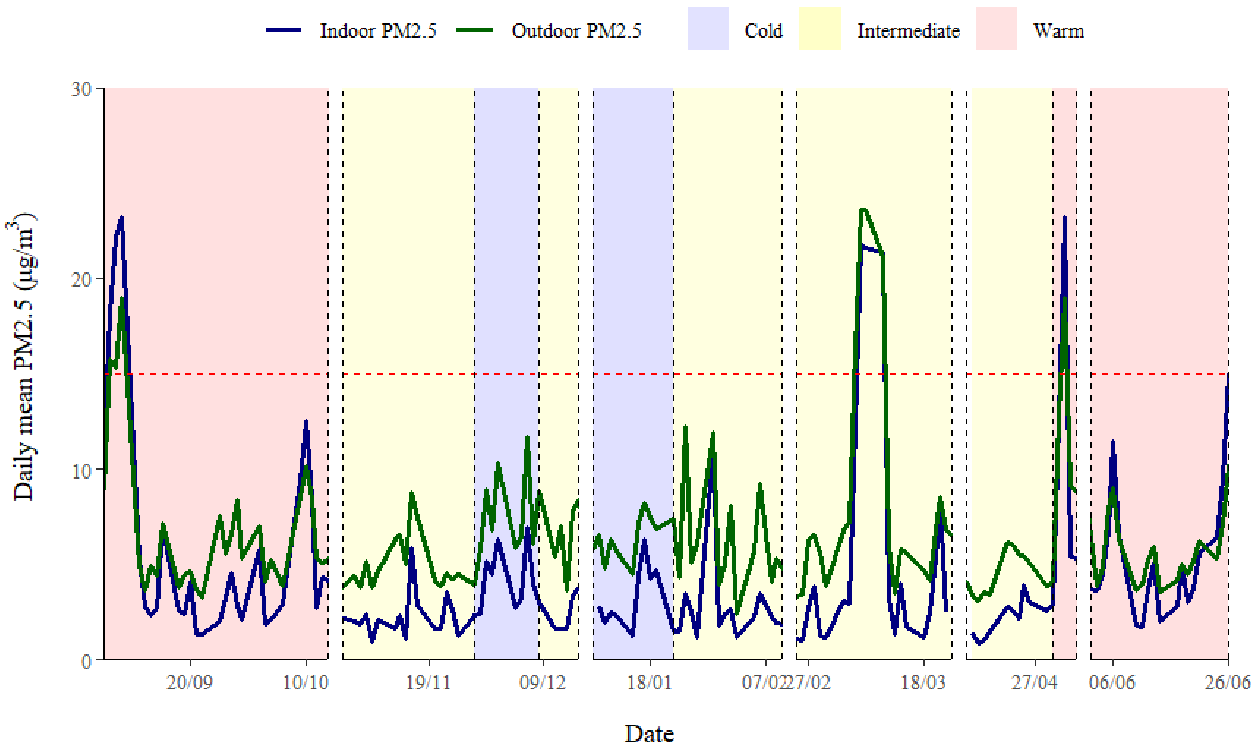

Figure 6: Indoor and outdoor daily mean $PM_{2.5}$ concentrations for each school day. The horizontal dashed red line denotes the maximum daily mean value of 15 $\mu g/m^3$ $PM_{2.5}$ recommended by the World Health Organisation. The vertical breaks in data are school holiday periods as detailed above.

4 Acknowledgements

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

References

Chatzidiakou, L., Archer, R., Beale, V., Bland, S., Carter, H., Castro-Faccetti, C., Edwards, H., Finneran, J., Hama, S., Jones, R., Kumar, P., Linden, P., Rawat, N., Roberts, K., Symons, C., Vouriot, C., Wang, D., Way, L., West, S., Weston, D., Williams, N., Wood, S. & Burridge, H. 2023 Schools' Air Quality Monitoring for Health and Education: Methods and protocols of the SAMHE initiative and project. *Developments in the Built Environment* http://dx.doi.org/10.1016/j.dibe.2023.100266.

Defra AURN 2024 https://uk-air.defra.gov.uk/networks/site-types.

Department for Education 2018 BB 101: Ventilation, thermal comfort and indoor air quality 2018. www.gov.uk/government/publications/building-bulletin-101-ventilation-for-school-buildings.

World Health Organization 2023 *WHO ambient air quality database, 2022 update: status report*.

Public Health England 2018 Health matters: air pollution. https://www.gov.uk/government/publications/health-matters-air-pollution/health-matters-air-pollution.

The SAMHE Project Team 2024*a* Findings from Autumn term 2023 for SAMHE schools, SAMHE Champions, and other interested parties. https://samhe.org.uk/resources/SAMHE_Findings_from_Autumn_term_2023.pdf.

The SAMHE Project Team 2024*b* Findings from Spring term 2024 for SAMHE schools, SAMHE Champions, and other interested parties. https://samhe.org.uk/resources/SAMHE_Findings_from_Spring_term_2024.pdf.

West, S., Way, L., Archer, R., Beale, V., Bland, S., Burridge, H., Castro-Faccetti, C., Chatzidiakou, L., Kumar, P., Vouriot, C. & Williams, N. 2023 Co-designing an air quality web app with school pupils and staff: the SAMHE web app. *Citizen Science: Theory and Practice* http://dx.doi.org/10.5334/cstp.620.