Findings from Autumn term 2023 for SAMHE schools, SAMHE Champions, and other interested parties

The SAMHE project team

February 2024

1 Executive summary

Data on indoor air quality was recorded from hundreds of SAMHE schools during the Autumn term of 2023. All findings reported here are based on averages across all of those schools. 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 issues air quality monitors to schools which agree to take part in the research. It has deployed monitors to over 1 000 of them, and receives data from around 300 schools. This data is being analysed by scientists to provide evidence as to the air quality within 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 Autumn term 2023

Most classrooms in the UK are naturally ventilated. The level of ventilation is managed by the 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 heating and 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. The daily average of these outdoor temperatures is plotted as the green line in figure 1. Throughout this report 'daily average' values are taken as the mean of measurements made during occupied hours which are taken to be 09:00 to 16:00, on school days only, following the guideline for naturally ventilated classrooms (Department for Education, 2018). Dashed horizontal lines indicate the temperatures (13°C and 6°C) that we have used to classify the weather into a warm period (up to mid-October) and a cold period (in late-November and early-December), separated by two intermediate temperature periods. Throughout our analysis, we highlight data associated with warmer outdoor temperatures using a pink-red background, cooler periods are highlighted with a blue-lilac background, and intermediate using yellow.

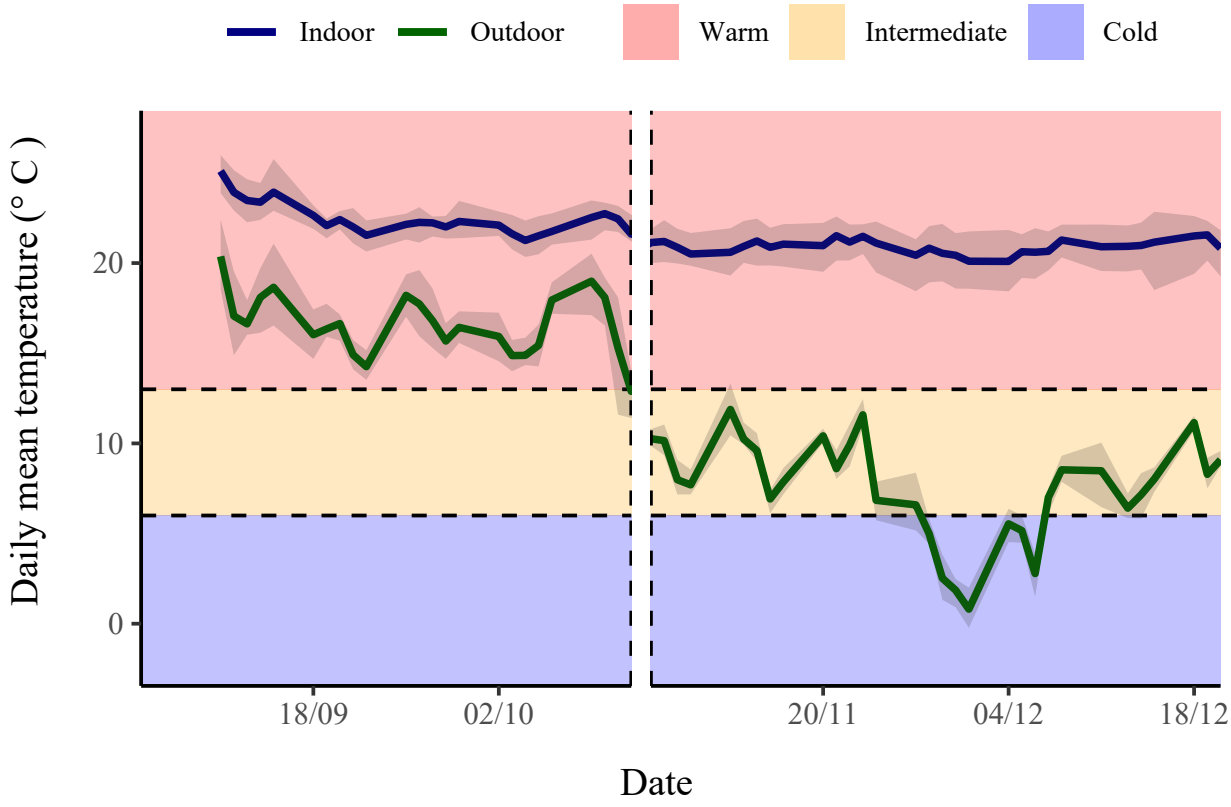

Figure 1: Daily mean temperature within SAMHE schools (marked by the green line) and outdoors (marked by the blue line). Horizontal bands of colour indicate the outdoor temperature ranges deemed to be warm, intermediate, and cool. The shaded areas illustrate the interquartile range of the data.

Figure 2 highlights four weather periods during Autumn 2023, as classified by the outdoor temperature ranges identified in figure 1. These four periods are indicated using vertically banded colours. Dashed horizontal lines show the average temperature during each period and we can see significant variation in outdoor temperature between the four periods. By contrast, the temperatures recorded by the SAMHE monitors — labelled "indoor" and marked by the blue line in figures 1 and 2 — are not significantly between the intermediate and cooler periods, and are only slightly increased during the warmer period. Higher indoor temperatures during the warmer period are to be expected as most classrooms do not have any provision for cooling, i.e. air conditioning. It is reassuring to observe that during the intermediate and cooler periods of outdoor, indoor temperatures measured by the SAMHE monitors don't vary greatly, staying at comfortable levels - these classrooms were able to be kept within a narrow temperature range even during cold weather, presumably by heating and for the occupants' comfort.

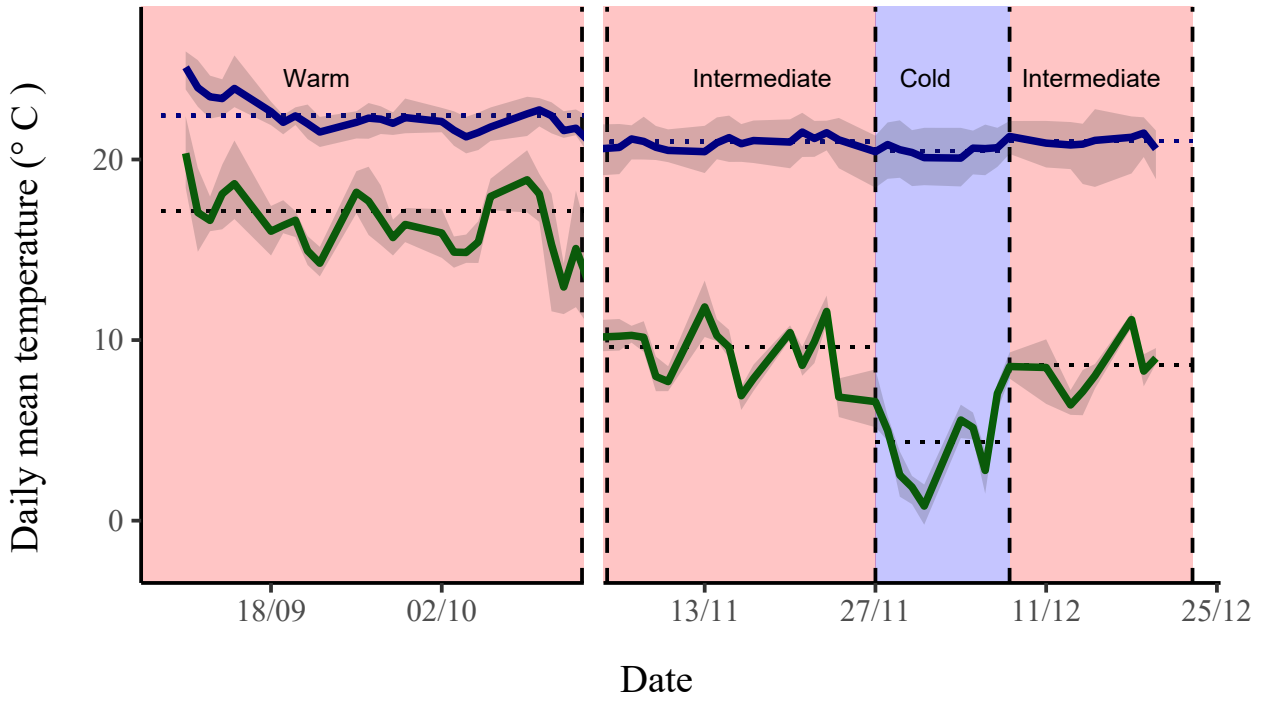

Figure 2: The same daily mean temperature across SAMHE schools that was plotted in figure 1, here presented using vertical bands of colour to indicate date periods associated with the warmer, intermediate, and cooler outdoor temperature.

Figure 3 shows the daily mean CO_2 concentrations across SAMHE schools over the same period. The mean CO_2 concentrations provide a good indication of the average per person ventilation supply to classrooms. The 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 temperature. However, there are still differences in the mean CO_2 level between the different weather periods: in the warmer (pink) period, CO_2 levels are significantly lower than the cooler (blue) period, with CO_2 levels in the intermediate periods lying between these two. 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 significant proportion of classrooms regularly exceeded this, whereas this was not the case in the warm period. This suggests that trying to keep classrooms warm during colder weather is a barrier to providing adequate ventilation. It is not clear whether education and training of classroom staff regarding ventilation behaviours might mitigate this, or whether the architecture, building services and maintenance of the school estates is a more significant barrier. The SAMHE methodology (Chatzidiakou *et al.*, 2023) is designed to be flexible in its data gathering, providing the potential for it to be used to seek answers to these, and other, questions.

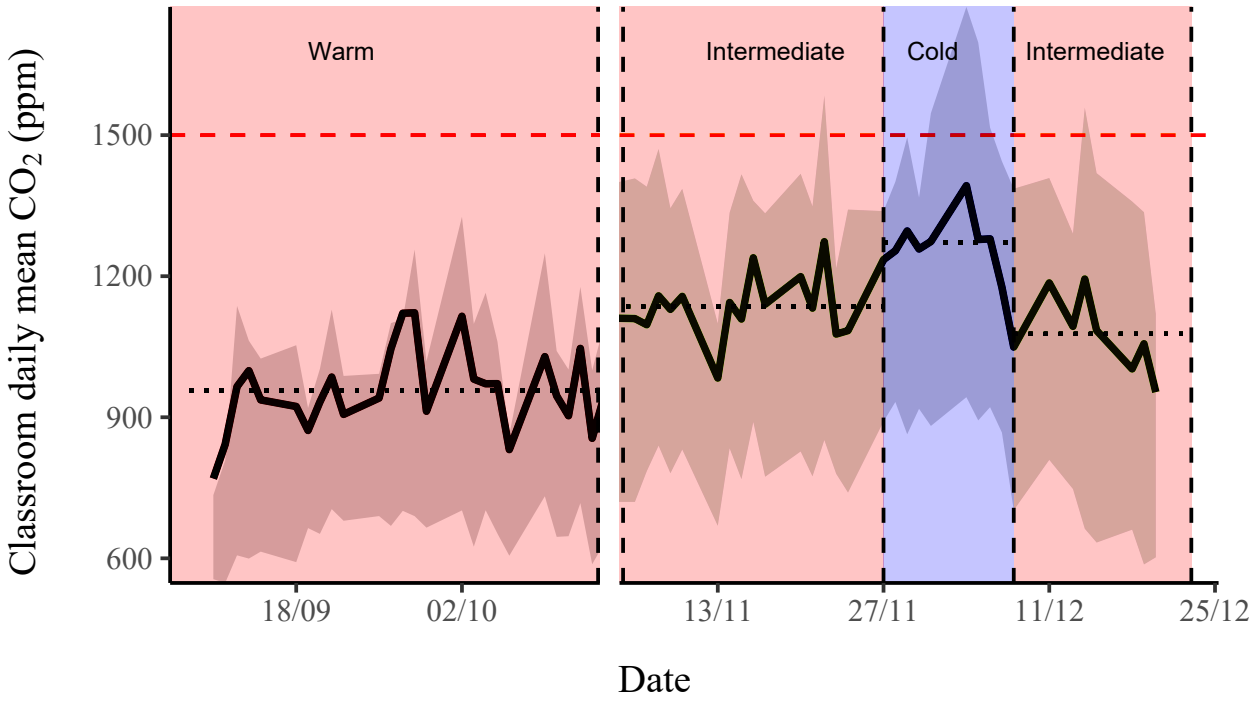

Figure 3: Daily mean CO_2 concentrations for each school day, with the dotted horizontal lines indicating the mean during each weather period, and the horizontal dashed red line denoting the BB101 guideline value of 1 500 ppm. The shaded areas illustrate the interquartile range of the data.

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. Interestingly, the trends in relative humidity over the weather periods are the opposite of those in the CO_2 data. Whilst CO_2 concentrations within the outdoor air vary relatively little over the course of one school term, relative humidity varies significantly 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.

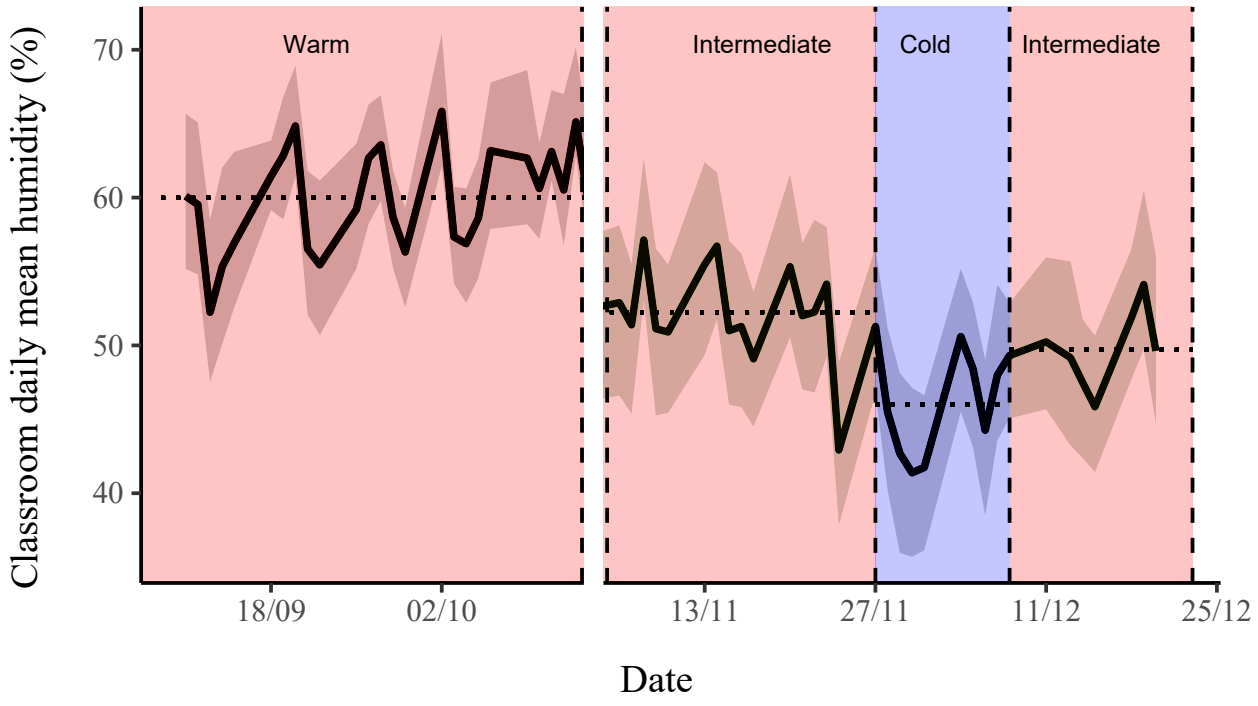

Figure 4: Daily mean relative humidity for each school day. The horizontal dotted lines show the mean during each weather period, and the shaded areas illustrate the interquartile range of the data.

Figure 5 shows the daily 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 of the measured $PM_{2.5}$ concentrations with outdoor temperature, with the averages during both the warm and cool periods lying above those in the intermediate periods. This indicates that outdoor temperature does not significantly affect the $PM_{2.5}$ concentrations in these classrooms. There is a moderate spike in $PM_{2.5}$ evident in mid-October, which was apparent in many SAMHE schools and also in outdoor PM measurements across the country. This suggests that $PM_{2.5}$ levels in classrooms might be influenced not only by activities inside and local conditions outside of the schools, but also by regional and international conditions and events. 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.

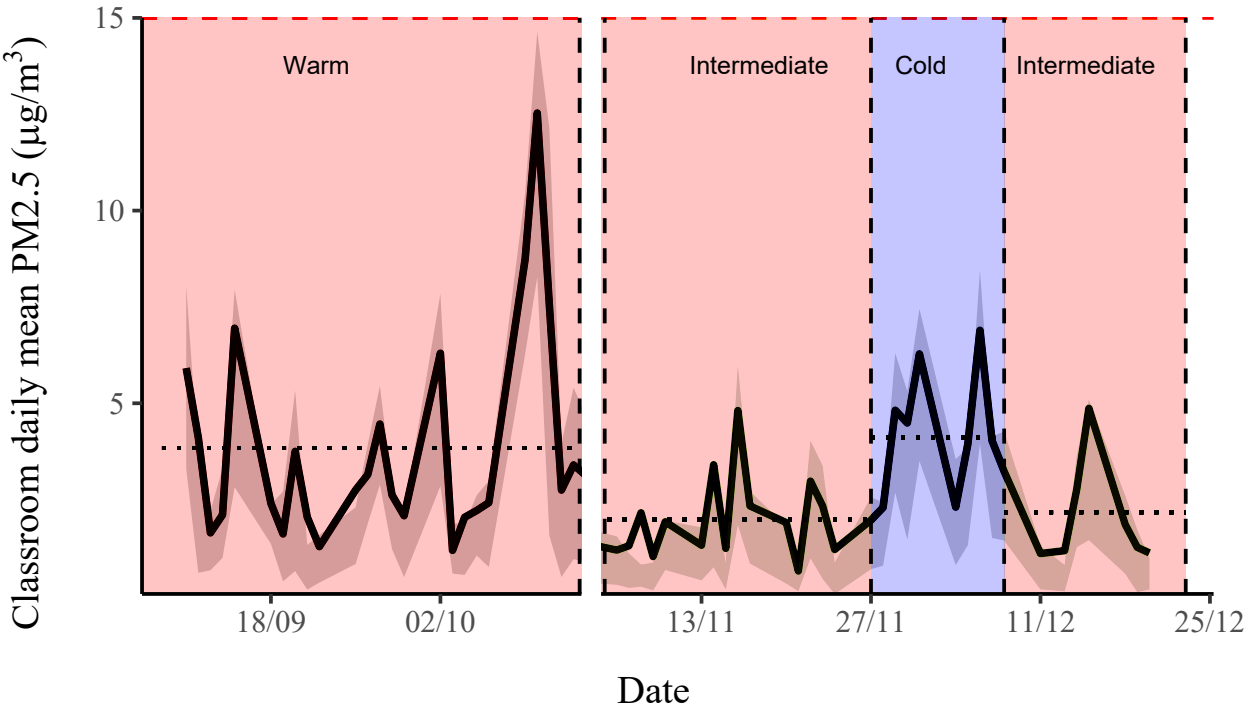

Figure 5: Daily mean $PM_{2.5}$ concentrations for each school day, with the dotted horizontal lines indicating the mean during each weather period, and the horizontal dashed red line denoting the maximum daily mean value of of 15 $\mu g/m^3$ $PM_{2.5}$ recommended by the World Health Organisation. The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

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

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