SAMHE
SCHOOLS' AIR QUALITY MONITORING FOR HEALTH AND EDUCATION

Findings from Spring term 2024 for SAMHE Schools, SAMHE Champions and other interested parties

The SAMHE project team

July 2024

1 Executive summary

This report discusses findings from SAMHE data collected during the Spring term 2024 and will be discussed in relation to the SAMHE Findings from Autumn term 2023 report (The SAMHE Project Team, 2024).

Data on indoor air quality was recorded from hundreds of SAMHE schools during the Spring term of 2024. All findings reported here are based on averages across all of those schools and reinforce findings discussed in the Autumn term 2023 report. Analysis of the data on carbon dioxide (CO_2) levels again 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 1 300 schools and currently receives data from over 700 of these monitors in schools. This data is being analysed by scientists to provide evidence of 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 Spring term 2024

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. We defined the Spring Term 2024 from 15^{th} January to 22^{nd} March and the half-term break from 10^{th} to 25^{th} February to account for variability in school term dates across the UK. Data was taken from 361 monitors in schools which were actively collecting data continuously across the defined Spring term 2024. The daily average of these outdoor temperatures, over the Spring term 2024, is plotted as the green line in figure 1. Throughout this report 'daily average' values refer to the mean of values measured in occupied hours, defined as from 09:00 to 16:00 on school days only (which allows comparison against Department for Education (2018)). Dashed horizontal lines indicate the temperature thresholds that we have used to classify the weather into a cold period (up to mid-January) and an intermediate period (mid-January through March) — we keep these temperature thresholds as 6°C and 13°C for consistency with those used in our SAMHE Findings from Autumn term 2023 report (The SAMHE Project Team, 2024). Throughout our analysis, we highlight data associated with warmer outdoor temperatures using a pink-red background, cold outdoor temperatures using a blue-lilac background and intermediate periods are highlighted with a yellow background.

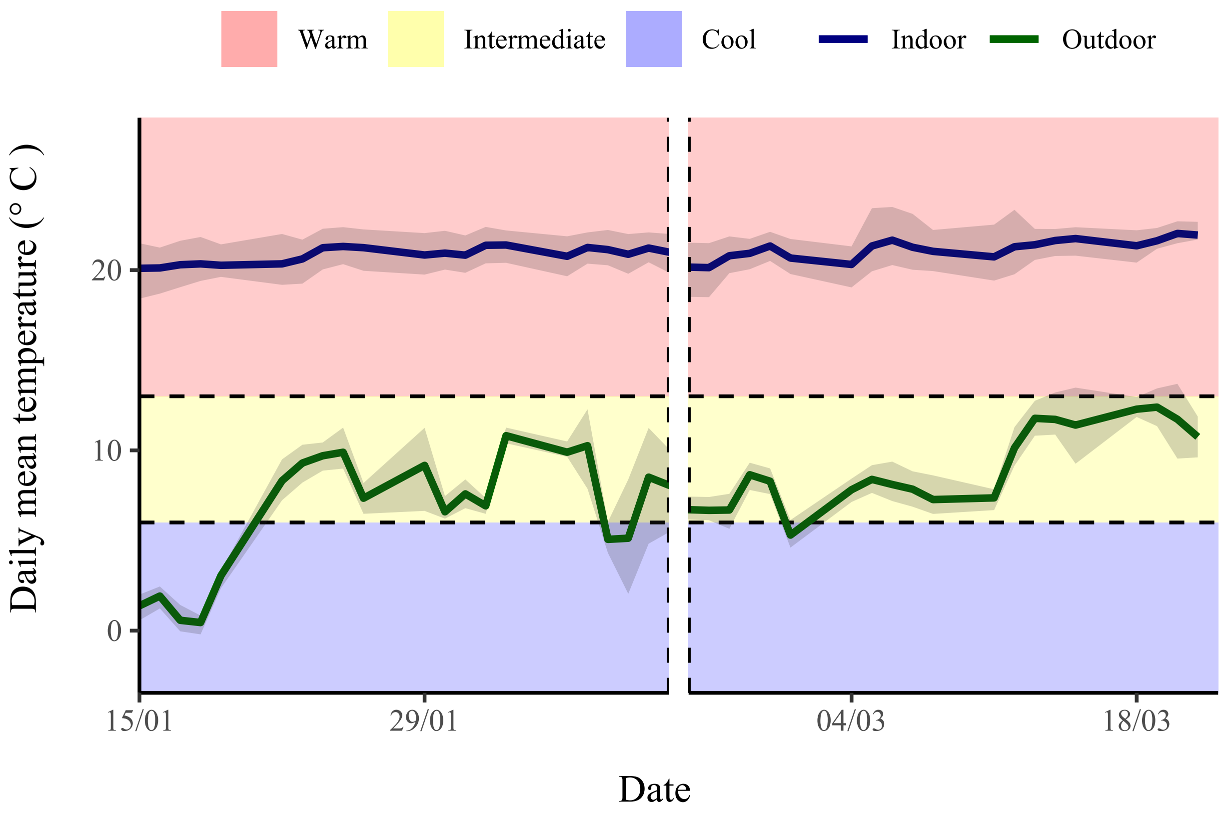

Figure 1: Daily mean temperature within SAMHE schools (marked by the green line) and outdoors (marked by the blue line). Horizontal bands of colour indicate the outdoor temperature ranges deemed to be cold, intermediate and warm. The shaded areas illustrate the interquartile range of the data. The vertical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

Figure 2 highlights two weather periods during Spring term 2024, as classified by the outdoor temperature ranges identified in figure 1. These two periods are indicated using vertically banded colours. The break in the plot (vertical white band) indicates a two week period of half term, during which most schools were off for 1 or 2 weeks. Dashed horizontal lines show the average temperature during each period and we can see an increase in outside temperature from just above 0°C (blue banded area on figure 2) to fluctuating around 10°C (yellow banded area on figure 2). By contrast, the indoor temperatures recorded by the SAMHE monitors — marked by the blue line in figures 1 and 2 — do not differ significantly between the cold and intermediate periods. This reassuring trend showing stable indoor conditions was also observed in the SAMHE Autumn term 2023 data where it was noted that the indoor temperatures remained at comfortable levels throughout, presumably due to heating.

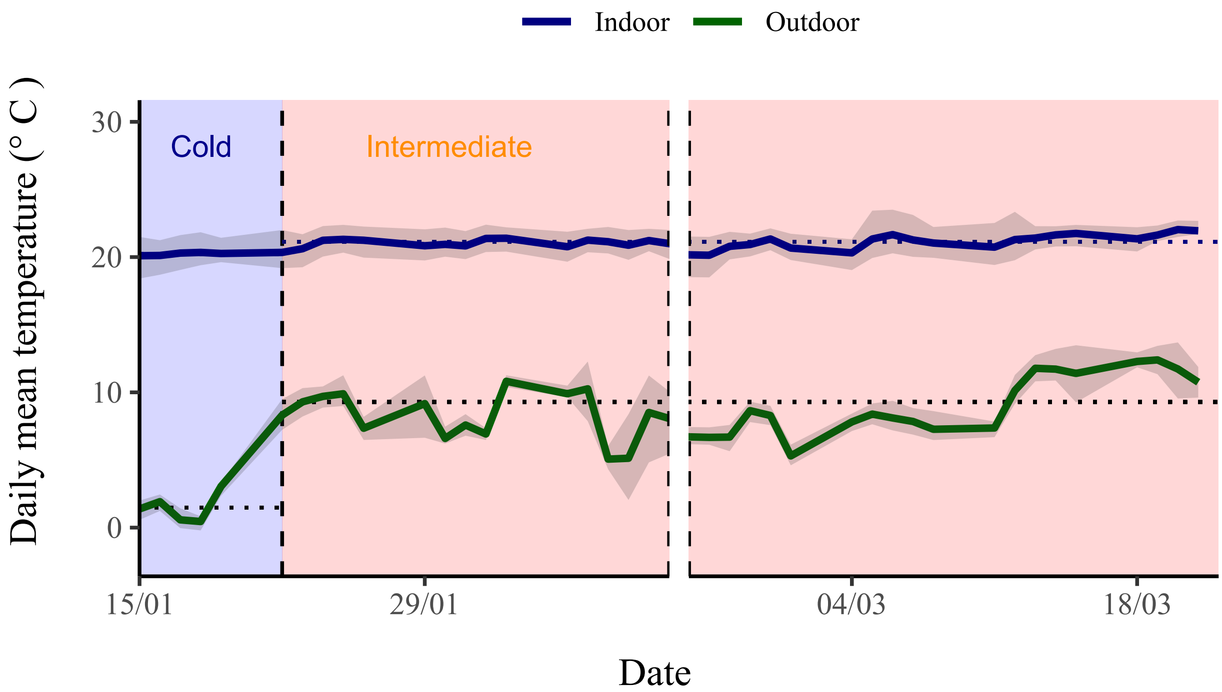

Figure 2: The same daily mean temperature across SAMHE schools that was plotted in figure 1, here presented using vertical bands of colour to indicate date periods associated with the cold and intermediate outdoor temperature. The shaded areas illustrate the interquartile range of the data. The vertical break in data is February half-term.

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. As found in the Autumn term 2023 report, 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. In contrast to the Autumn 2023 report, the daily mean CO_2 levels remained fairly consistent throughout this term, probably because outdoor temperature, and hence window opening, did not vary as greatly. Overall, mean CO_2 levels across all SAMHE schools were lower in the Autumn term 2023 compared with the Spring term 2024. This is likely due to the prolonged period of warmer weather experienced during the Autumn term which led to windows being open more often, providing better ventilation therefore lower CO_2 levels.

During the cooler period right at the start of the Spring term (shown by the blue shaded area), mean daily CO_2 levels are elevated. During the Autumn term 2023, we also observed increased daily mean CO_2 levels when outside temperatures were cold, strengthening 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 cold period at the start of term a proportion of classrooms exceeded this daily threshold; during the intermediate period this was exceeded again when outside temperatures edged towards the cooler limit. This supports our previously reported conclusion that trying to keep classrooms warm during colder weather is a barrier to providing adequate ventilation (The SAMHE Project Team, 2024). 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 help seek answers to these, and other, questions.

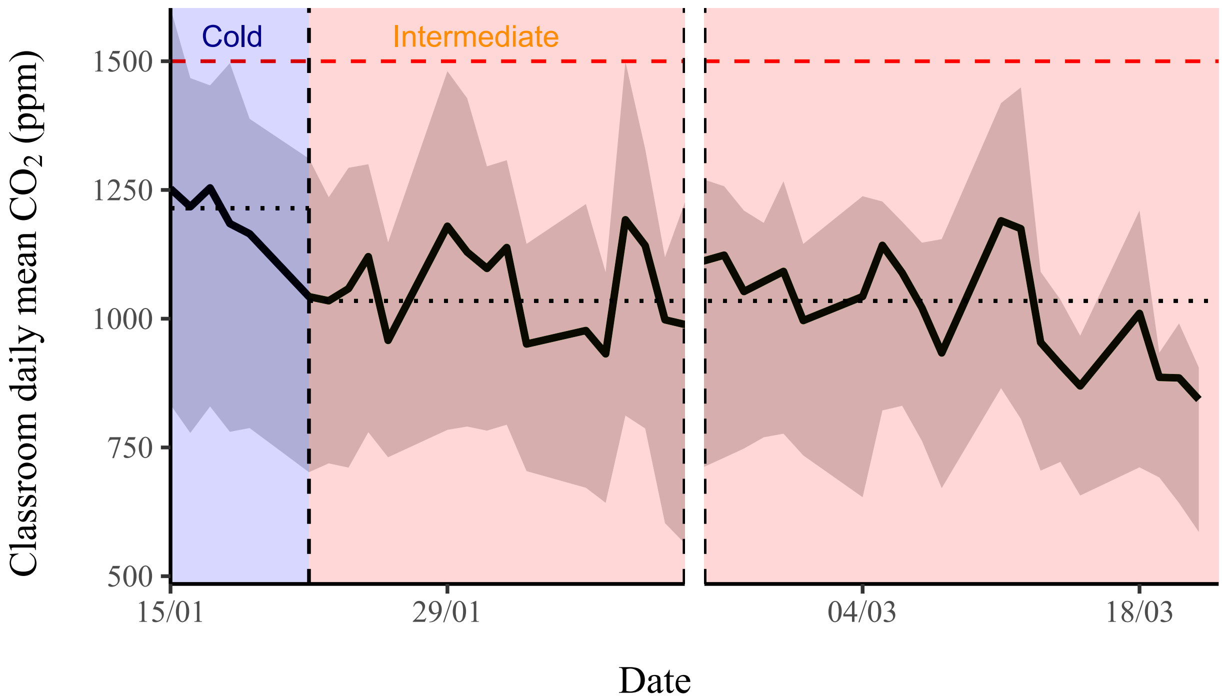

Figure 3: Daily mean CO_2 concentrations for each school day, with the dotted horizontal lines indicating the mean during each weather period, and the horizontal dashed red line denoting the BB101 guideline value of 1 500 ppm. The shaded areas illustrate the interquartile range of the data. The vertical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

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 (Finneran & Burridge, 2024). Our breath is also rich in moisture and hence contributes to humidity. Figure 4 shows the relative humidity data gathered by the SAMHE monitors. As found in the Autumn term 2023 report, 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.

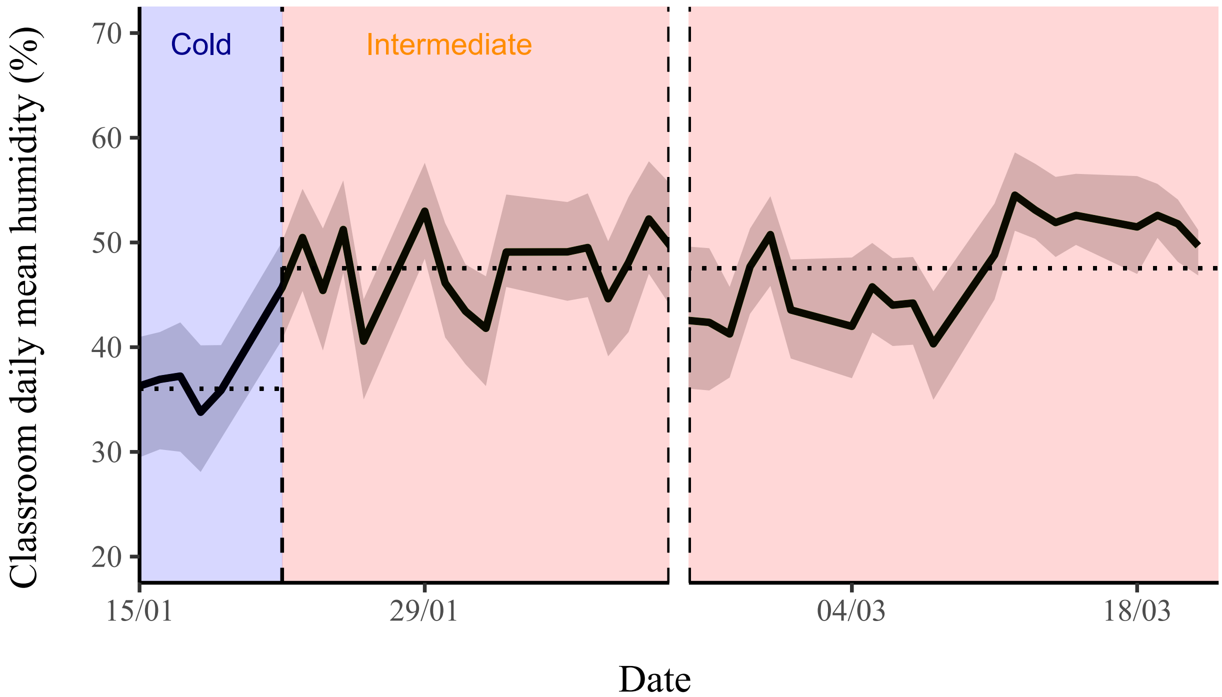

Figure 4: Daily mean relative humidity for each school day. The horizontal dotted lines show the mean during each weather period, and the shaded areas illustrate the interquartile range of the data. The vertical break in data is February half-term.

Figure 5 shows the daily mean $PM_{2.5}$ concentrations measured by the SAMHE monitors, which for the majority of the term lie 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 cold and intermediate periods lying around $5\,\mu g/m^3$. This indicates that outdoor temperature does not significantly affect the $PM_{2.5}$ concentrations in these classrooms. There is a significant spike in $PM_{2.5}$ in March, which was apparent in many SAMHE schools and also in outdoor PM measurements across the country. Possible causes of $PM_{2.5}$ spikes could be from sulphur containing fuels such as coal, ammonia (NH3) which is largely due to agricultural sources such as livestock waste, nitrates formed by the oxidation of nitrogen oxides and nitrogen dioxide in the atmosphere, and/or sulphate which can react with ammonia to form ammonium sulphate (Aerosol Science Dashboard, 2024). This reinforces our previously reported finding that $PM_{2.5}$ levels in classrooms are 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.

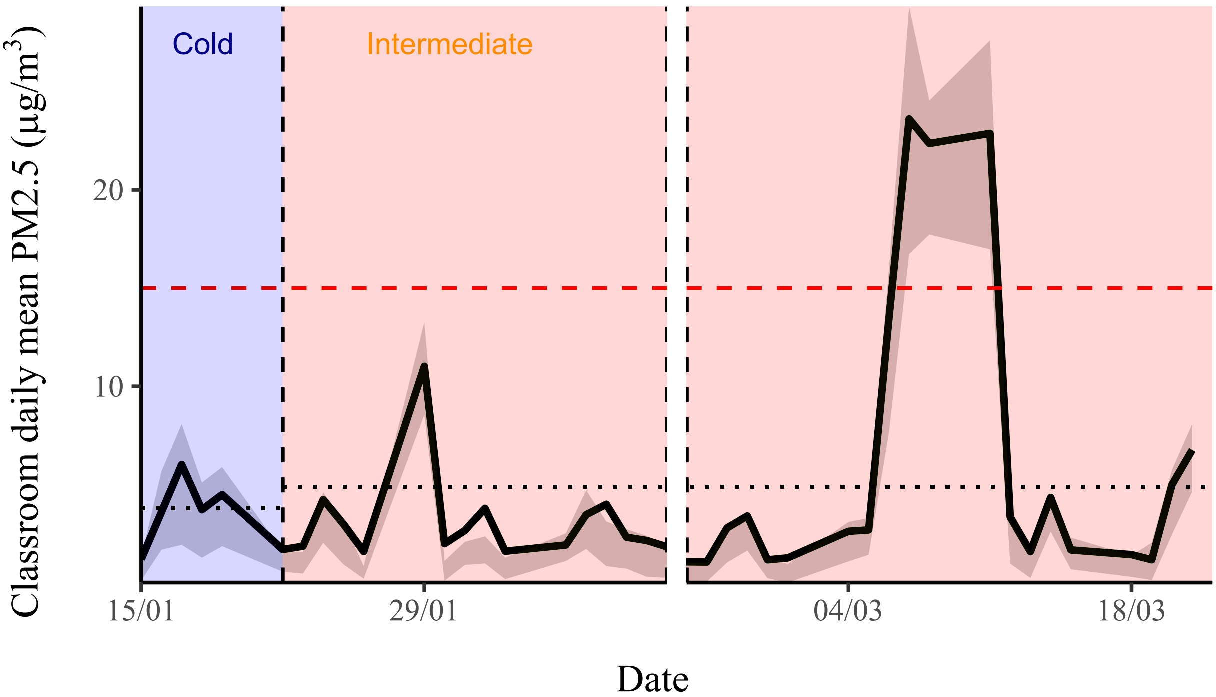

Figure 5: Daily mean $PM_{2.5}$ concentrations for each school day, with the dotted horizontal lines indicating the mean during each weather period, and the horizontal dashed red line denoting the maximum daily mean value of $15\,\mu g/m^3$ $PM_{2.5}$ recommended by the World Health Organisation. The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

Figure 6 shows the chemical composition and sources of measured $PM_{2.5}$ data taken from DEFRA AURN London Honor Park monitoring site (Aerosol Science Dashboard, 2024). This figure shows the measured chemical composition that can be used as an indicator of chlorine (Cl - sea salt produced from breaking waves), ammonium (NH_4 - agriculture), nitrate (e.g. NH_4NO_3, both distant and local sources (traffic, and domestic heating)), sulphate (e.g. $(NH_4)_2SO_4$, industry), organic mass (both local (traffic, wood burning and cooking) and distant source) and black carbon (diesel vehicles and wood burning). As mentioned above, the indoor measured $PM_{2.5}$ shown in figure 5 correlates to the outdoor $PM_{2.5}$ trends displayed in figure 6. From figure 6, we can infer that during the $PM_{2.5}$ spike in March there were higher proportions of ammonium, nitrate and sulphate in the air compared to the annual averages of 2023 and 2024 (Aerosol Science Dashboard, 2024).

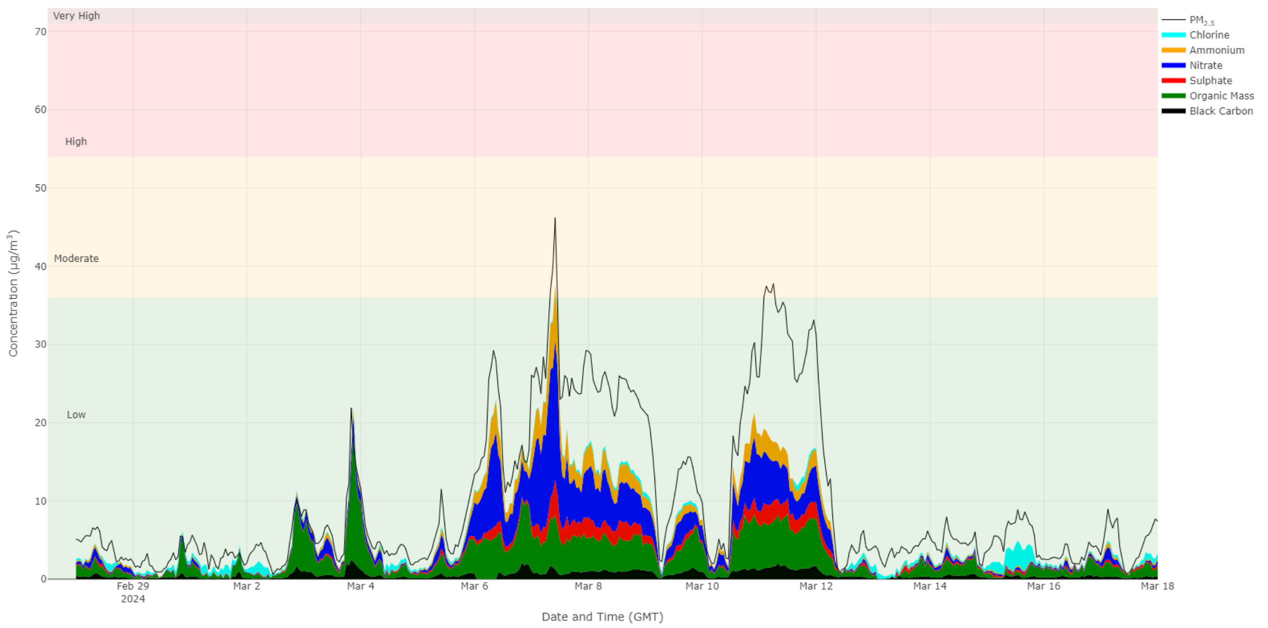

Figure 6: Time series of chemical composition of $PM_{2.5}$ in London background (Aerosol Science Dashboard, 2024)

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.

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