The impact of fireworks events on classroom air quality

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March 2024

1 Introduction

In the Autumn of every year, there are two events in the UK which are often celebrated by the lighting of fireworks: Bonfire night (or Guy Fawkes night) and Diwali. Bonfire night is on the 5$^{\text{th}}$ November every year, with big celebrations running over the weekend of Friday 3$^{\text{rd}}$ to Sunday 5$^{\text{th}}$ November in 2023. In 2023, Diwali occurred on the 13$^{\text{th}}$ November, with many celebrations focused over the period Friday 10$^{\text{th}}$ to Monday 13$^{\text{th}}$ November. When set off, fireworks burn chemicals and so affect air pollution levels. Most noticeably for the measurements made by the SAMHE monitors, fireworks release particulate matter into air outdoors.

Children, young people and teachers spend lots of their time in school classrooms and so it is important to monitor and better understand air quality, including the concentration of particulate matter, in school classrooms. In this technical report, we use the levels of $PM_{2.5}$ recorded by air quality monitors, connected to the Schools' Air quality and Monitoring for Health and Education (SAMHE) project, to investigate whether the Autumn's fireworks events had a noticeable effect on the indoor air quality of SAMHE classrooms.

2 Indoor and outdoor PM concentrations

To find the outdoor concentration of $PM_{2.5}$ around SAMHE schools, data from the nearest Defra station, monitoring background outdoor air quality, to each school was used (Defra is the Government's Department for Environment, Food & Rural Affairs). The hourly concentrations of $PM_{2.5}$ was averaged across all of these stations and then compared to the hourly average concentration of $PM_{2.5}$ from the SAMHE air quality monitors. Figure 1 shows the hourly mean concentration of $PM_{2.5}$ averaged across SAMHE monitors (in red, 'Indoor') and averaged across the Defra stations (in blue 'Outdoors'). These trends are shown over a four week period which includes the two consecutive weeks in which Bonfire night and Diwali both fell, as well as more 'typical' weeks before and after the weeks of the firework events. The days of Bonfire night and Diwali are each highlighted by vertical coloured bands, as are the Saturdays nearest to each event (on where many celebrations are likely to have occurred).

Across the entire period shown, the outdoor levels of $PM_{2.5}$ are higher than the levels in classrooms. On the evenings of the 4$^{\text{th}}$, 5$^{\text{th}}$ and 11$^{\text{th}}$ November, the outdoor levels of $PM_{2.5}$ are significantly higher than at other times. The levels of indoor $PM_{2.5}$ from the SAMHE monitors seem closely correlated to the outdoor levels. Specifically, the peaks in indoor $PM_{2.5}$ occur very soon after peaks in outdoor $PM_{2.5}$ (on average around two hours later). Over this period, the highest concentration of $PM_{2.5}$ is on Saturday 11$^{\text{th}}$

November, the Saturday after Bonfire night and before Diwali. The $PM_{2.5}$ concentration was also higher over Bonfire night weekend (Saturday 4^{th} and Sunday 5^{th} November) than in the week before or after. It is also worth noting that the indoor and outdoor levels on Thursday 16^{th} and Friday 17^{th} November are similar to those over Bonfire weekend. Whilst it is possible that belated fireworks celebrations occurred over these dates there may be other, unexplained, contributions to the higher levels of $PM_{2.5}$.
In order for sources of outdoor pollutants, such a the particular matter produced by fireworks, to be present within indoor air, they must be carried by the air flows into buildings; these are described as ventilation flows, and often occur through windows, doors and ventilation openings. It may seem surprising then that the levels of indoor $PM_{2.5}$ were high over the weekends of Bonfire night and Diwali, as it could be expected that the ventilation of schools would be reduced at weekends as doors and windows should be shut for security reasons. These readings from the SAMHE monitors suggest that there might still be quite a lot of outdoor air ventilating these schools even at weekends.

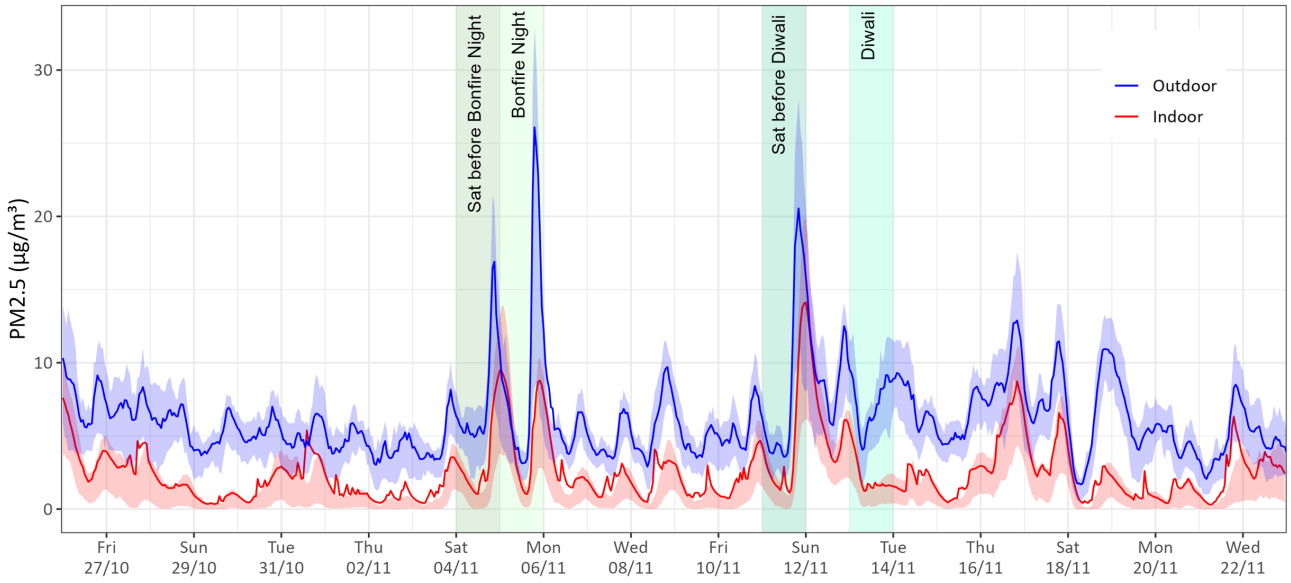

Figure 1: The hourly mean concentration of $PM_{2.5}$ ($\mu g/m^3$) against time between 26/10/23 to 23/11/23. The indoor measurement (in red) is the average of the concentration measured by all connected SAMHE classroom monitors. The outdoor measurement (in blue) is the average concentration across the Defra measurement sites closest to schools. The interquartile range is shown by the shaded region. The dates of Bonfire Night and Diwali and the nearest Saturday to each event are also highlighted in various shades of green.

Both Bonfire night and Diwali were predominantly celebrated at weekends, when pupils were not at school. Therefore, we next wished to establish whether these events had an impact on the air quality in classrooms during the school week that followed each celebratory weekend. Figure 2 shows the $PM_{2.5}$ concentrations measure but only those during school hours; so the data shown is the same as that shown in figure 1, but since school hours are just 7 hours per day, 5 days a week, figure 2 shows gaps within the data to help highlight levels during school time. The level of $PM_{2.5}$ in the week after bonfire night is not significantly higher than in the week before, so despite $PM_{2.5}$ permeating into school classrooms over the weekend, the levels had largely returned to be more 'typical' by the start of the school week. The level of $PM_{2.5}$ after

Diwali is higher than the week before, but still below the WHO recommended guideline of daily average of less than 15 μg/m^3.

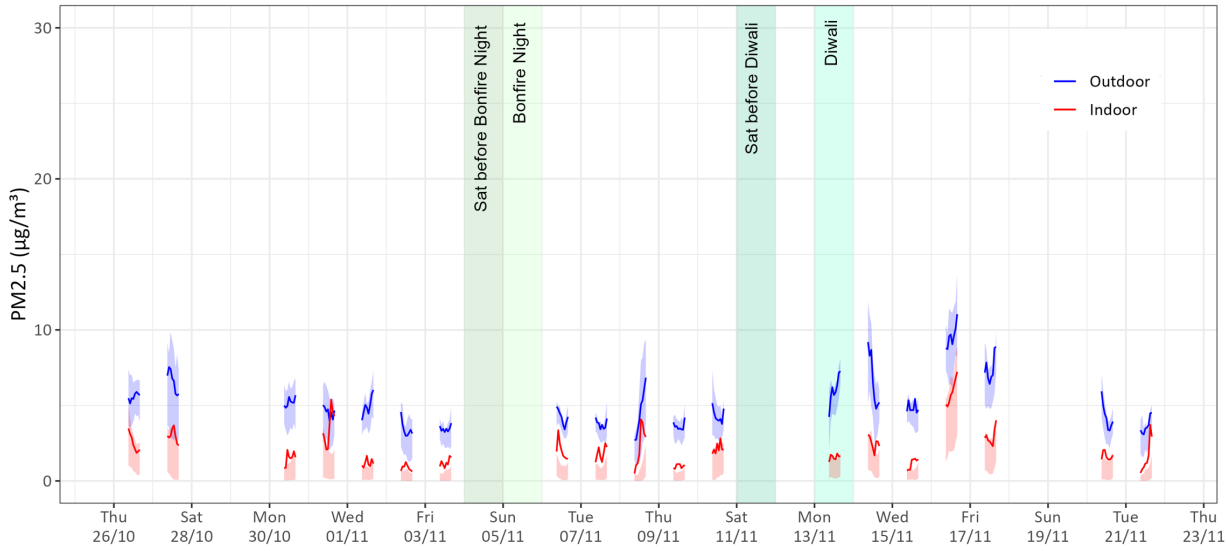

Figure 2: The hourly mean concentration of $PM_{2.5}$ (μg/m^3) against time during school hours (9:00 - 16:00, weekdays only). The indoor (red) and outdoor (blue) data is from the same source as in figure 1. The interquartile range is shown by the shaded region.

3 Discussion and Conclusions

In summary, outdoor levels of $PM_{2.5}$ significantly impact the levels indoors. A previous SAMHE technical report highlighted that during a Saharan dust storm in September 2023, the levels of $PM_{2.5}$ in school classrooms were elevated. Whilst both the fireworks events reported on here and the Saharan dust storm were detected by SAMHE classroom monitors, these two sets of events affected classroom air quality differently. The fireworks events were more spatially localised sources of $PM_{2.5}$ and occurred over a shorter period. The concentration of both outdoor and indoor $PM_{2.5}$ resulting from the fireworks events were lower than during the Saharan dust storm. Additionally, the fireworks events mostly occurred over the weekend; as a result, the fireworks events did not significantly increase the $PM_{2.5}$ levels during the school week when children were present - unlike during the Saharan Dust event.

The findings of this report indicate that these UK school classrooms are somewhat 'leaky' to the outdoors - $PM_{2.5}$ permeates indoors even over the weekends when schools are 'closed' and ventilation is likely reduced. However, this same 'leakiness' results in elevated $PM_{2.5}$ concentrations being reduced, and becoming more 'typical', before staff and pupil are likely to be present when the $PM_{2.5}$ sources are firework events.

Acknowledgements

The SAMHE team would like to thank all of the schools, teachers and pupils who have participated in the SAMHE project.