

Indoor Air Quality in Naturally Ventilated Classrooms and Offices

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ABSTRACT

Air pollution significantly affects global health, accounting for one in ten deaths worldwide. Schools represent crucial environments due to children's extended exposure and increased vulnerability to air pollution. The detrimental effects of poor indoor air quality (IAQ) in offices and classrooms are well documented, including chronic and acute health issues, reduced attendance rates, impaired academic and work performance, decreased productivity, and substantial socioeconomic consequences. Ventilation is essential for maintaining IAQ and thermal comfort by regulating the exchange of indoor and outdoor air. While numerous IAQ studies in offices and classrooms have focused on mechanically ventilated buildings, the effectiveness of natural ventilation in these environments is less extensively documented. The current study aims to characterise the spatial and temporal variation of key indoor air pollutants in naturally ventilated classrooms and offices, concentrating on identifying the primary building and occupancy-driven factors influencing IAQ. This study involved multi-zone IAQ monitoring in 2-4 locations across 17 buildings in Ireland, consisting of offices and classrooms, totalling 51 environments. PM_{2.5}, CO₂, temperature, relative humidity, and total volatile organic compounds were measured in real time over a week. Formaldehyde, BTEX, pinene, limonene, and NO₂ were collected through passive samples over a week, except for NO₂, which was measured over three weeks. Distinct patterns emerged between offices and schools, with CO₂ concentrations in classrooms being nearly double those found in offices during occupied periods. PM_{2.5} and NO₂ concentrations were significantly influenced by ambient pollution, with PM_{2.5} showing a strong correlation ($r=0.75$). Furthermore, 48% of monitored days surpassed the WHO 24-hour guidelines. Median formaldehyde concentrations were 19 $\mu\text{g}/\text{m}^3$ in offices and 20 $\mu\text{g}/\text{m}^3$ in classrooms, higher than the standards observed in previous studies. Significant spatial variation was noted both between and within buildings, with certain pollutants exhibiting greater variability within buildings than between them. Both indoor and outdoor temperatures were key factors influencing ventilation behaviour, particularly in classrooms, where lower temperatures were linked to elevated CO₂ concentrations. The results highlight the ongoing challenges in balancing thermal comfort, ventilation, and IAQ. These insights can inform policy development in naturally ventilated offices and schools, enabling evidence-based strategies to minimise exposure to indoor air pollution and enhance occupant health and well-being.

Keywords

Schools, offices, particulate matter, formaldehyde, CO₂.