Personal exposure to exhaled contaminants using a personalised exhaust system integrated in a hospital bed

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ABSTRACT

The control of airborne contaminants in hospital rooms is a critical requirement for ventilation engineering, particularly when exhaled aerosols interact with complex indoor flow structures. This study evaluated the effectiveness of two general ventilation strategies combined with a personalised extraction system (PES) integrated into a hospital bed.

Experiments were carried out in a mechanically ventilated full-scale chamber using two breathing thermal manikins configured as a contaminant source (patient) and a receiver (healthcare worker). Both operated under controlled respiratory boundary conditions, enabling quantification of particle concentration in the macroenvironment and in the microenvironment corresponding to the healthcare worker's breathing zone. Two ventilation configurations -upper–upper (UG–UG) and upper–lower (UG–LG)- were tested. The PES was installed either at the head or at the foot of the bed, enabling assessment of positional effects on personal exposure reduction.

Without PES assistance, UG–UG produced the highest exposure due to persistent recirculation cells that favoured re-entrainment of the exhaled plume, whereas UG–LG achieved lower background concentrations through a more efficient supply-to-exhaust flow path. Activation of the PES generated substantial exposure reductions in both ventilation regimes. In UG–UG, the PES decreased macroenvironment concentrations by 32–36% and microenvironment levels by 31–33%, demonstrating its capacity to disrupt the coupling between the buoyant exhaled jet and the coherent recirculation structures that dominate the room flow field. In UG–LG, where baseline exposure was lower, the PES achieved additional reductions of 8–13% in the macroenvironment and 8–17% in the microenvironment.

PES positioning exhibited a dominant influence on personal exposure. Locating the extraction at the foot of the bed consistently yielded the highest performance, with microenvironment reductions reaching up to 33%, compared with 17% when installed at the head. This behaviour is attributed to the earlier and more stable interception of the exhaled jet enabled by the foot end configuration, allowing its capture before dispersion and subsequent entrainment into the healthcare worker's inhalation flow.

These findings confirm that hospital bed-integrated local exhaust constitutes an effective personalised environmental control measure capable of reducing near-field exposure beyond what is achievable with general ventilation alone, supporting its integration into resilient ventilation strategies for airborne infection control.

KEYWORDS

Personalised exhaust system, hospital airborne exposure, breathing thermal manikins, contaminant dispersion control, ventilation effectiveness