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Airborne Pathogen Monitoring and Ventilation Assessment on Passenger Ships

Large passenger ships are characterised as enclosed/crowded spaces with frequent interactions, providing conditions that facilitate disease transmission. Moreover, super-spreading events (Abe et al., 2022; Althouse et al., 2020) have been reported to have occurred in these environments. The COVID-19 pandemic demonstrated a profound inability of existing passenger ship policies to detect/address newly developing diseases. To enhance the passenger experience, this research has conducted three sets of studies: (i) systematic literature review (Kumar et al., 2025), (ii) exhaled tracer gas experiments (Hama et al., 2025 (in preparation), (iii) localised CO2 monitoring (Cheung et al., 2025). The goal of these studies is to achieve a comprehensive understanding of indoor environmental quality (IAQ), ventilation conditions, aerosol dispersion and respiratory disease infection risk aboard.

The first study is a systematic literature review, the search was developed to (i) examine typical concentrations of airborne aerosols and ventilation parameters aboard, and instruments used for monitoring; (ii) assess existing methods for understanding infectious risk. Followed by controlled conditions tracer gas experiments and CO2 mapping conducted onboard a sailing cruise ship. The tracer gas experiment aims to achieve an understanding of the ship's infiltration rate and ventilation performance in controlled conditions. Two shipboard spaces were selected, each having a CO2 cylinder (CO2) and a nebuliser with KCl solution (particles). Sensors were installed around the room. The release of CO2 was controlled by flow rate and temperature. Six heat blankets were used to generate a fluctuation in CO2 and aerosol dispersion. The localised study aims to investigate ventilation conditions and identify the risk of transmission of airborne disease. Thus, to deliver actionable recommendations on the ventilation operation. IAQ monitoring was conducted in nine environments (three cabins, buffet, gym, bar, restaurant, pub, and theatre). CO2 concentrations, temperature, and relative humidity were monitored.

The review suggests that future studies should focus on obtaining airborne aerosol dispersion data under controlled experimental conditions and real-world shipboard environmental parameters, that are suitable for the development of a framework for a diverse range of passenger ship environments.
The tracer gas experiment shows an understanding of airflow behaviour and the accompanying dispersion of exhaled droplets. Horizontal and vertical variations of CO2 and particles are found to understand spatial variation of CO2 and particles in ventilated-controlled rooms. This work produced high-resolution data for validating the detailed numerical models for a large passenger ship. The localised monitoring found the probability of airborne infection transmission during normal speaking conditions to be very low (<3%). However, in higher occupancy areas where voices are raised to be heard (dining areas and social settings at peak times), CO2 levels increased, suggesting additional mitigatory measures are required. It also identified challenges from port emissions impacting IAQ aboard the cruise ship, with elevated ambient CO2 levels in berths.

This study sets the stage for further exploration and provides practical recommendations for the optimisation of ventilation operations in passenger ships, contributing to providing a safe sailing environment and resilience for future pandemics.

Reference

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