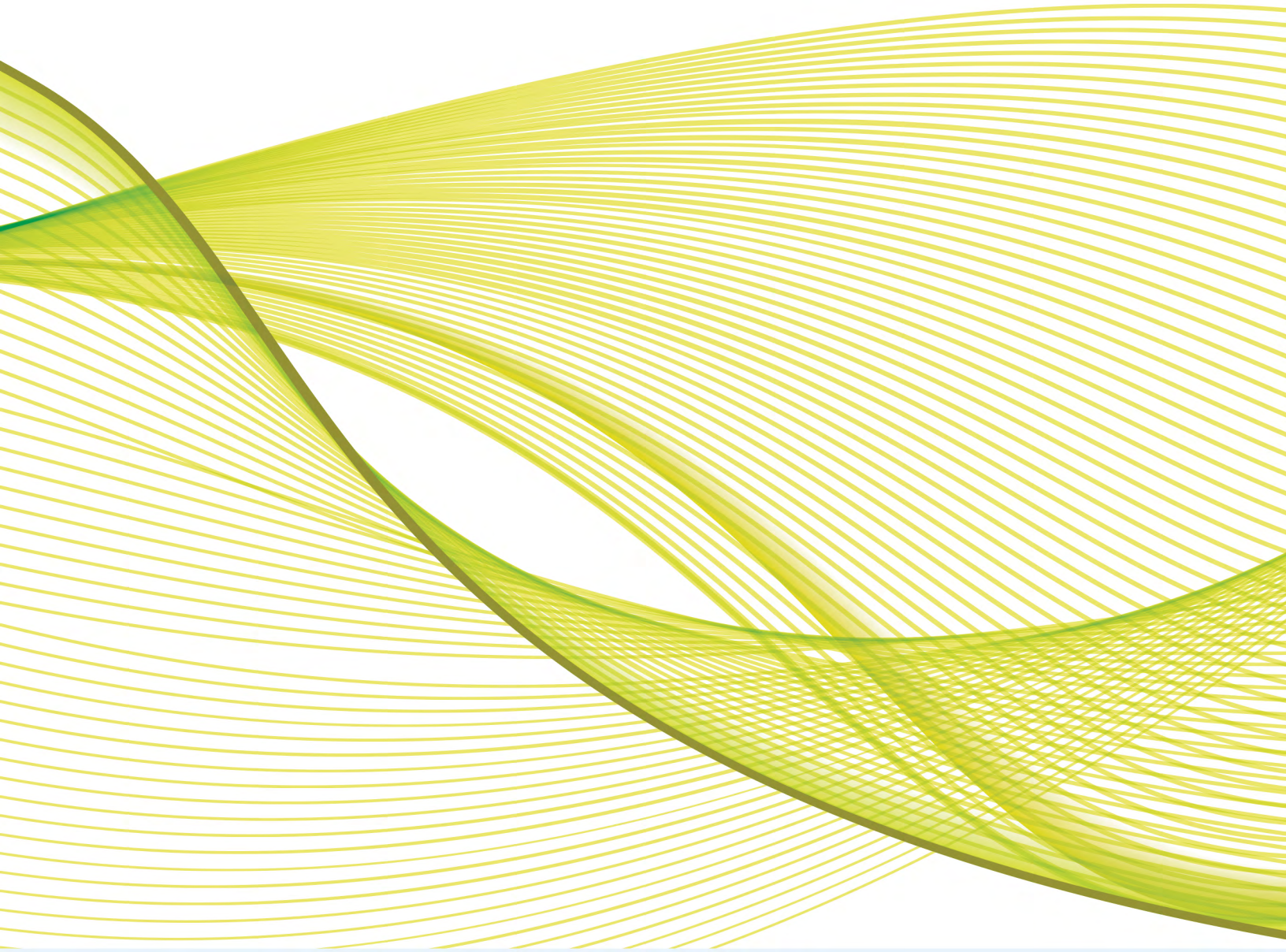
Transportation



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Transportation vessels pose unique challenges in mitigating airborne disease transmission due to their confined and densely populated spaces.[1] To reduce the risk of transmission, effective tools for source control, such as wearing masks and limiting talking, can be implemented because fewer infectious aerosols are released when people are silent.[2]

OSPE recommends an equivalent clean air delivery rate of 10 litres per second per person in passenger cabins. A range of tools are available to improve air quality in transportation vehicles.[3]

General Methods for Indoor Air Quality Improvement

GTo improve the air quality on public transportation, a combination of methods can be implemented. Most vehicles have mechanical ventilation systems that should run continuously when passengers are on board. Some systems supply a combination of outdoor air and recirculated air. Some systems can be set to only recirculate air instead of bringing in outdoor air. These should always be taken off recirculation mode when occupied. Windows should be opened as much as possible to allow for natural ventilation. During colder weather, a few windows can be kept open slightly to improve ventilation rates while still maintaining passenger comfort.

When outdoor air quality is poor, for example, during wildfire smoke, opening windows can be detrimental to air quality. Recirculated air can be cleaned by using high-efficiency filters that are compatible with existing systems.[4] Efficient filtration can also mitigate exposure to fine particulate matter pollution, especially in areas with poor outdoor air quality, like busy roads or subways.[5]

In-duct **ultraviolet (UV)** systems are an alternative to higher efficiency filters to disinfect recirculated air.[6] Whole-room far-UV systems are an emerging technology that can be considered, provided they are shown to be safe and effective. Space permitting, in-room filtration such as ceiling-mounted HEPA filtration units can be added. Additive air cleaning technologies such as ionization, plasma, or ultraviolet photocatalytic oxidation should be avoided.

Automobiles

Achieving high airflow rates in automobiles can be accomplished through natural ventilation. Weather permitting, windows can be fully opened. For optimal ventilation at high speeds, opening windows diagonally on opposite sides of the vehicle is recommended.[7] The climate control system can be set to the highest fan speed and not to recirculate air. Standard cabin air filters often have high efficiencies

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[1] N. J. Edwards et al., “Reducing COVID-19 Airborne Transmission Risks on Public Transportation Buses: An Empirical Study on Aerosol Dispersion and Control,” *medRxiv*, p. 2021.02.25.21252220, Mar. 2021, doi: 10.1101/2021.02.25.21252220.
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against fine particulate matter.[8] Upgrading the cabin air filter to a HEPA filter can further mitigate exposure to outdoor air pollution and provide equivalent clean air when the system is set to recirculate.

School Buses

To improve air quality on school buses, a combination of natural ventilation and mechanical ventilation can be used. Weather permitting, windows can be fully opened. It is important to note that school buses typically do not have **Heating, Ventilation, and Air Conditioning (HVAC)** in the passenger area; rather, they rely on natural ventilation. In colder weather, one out of every three windows should be slightly lowered. There are two hatches on the roof with an exhaust fan on the rear hatch. These hatches can be opened, and the exhaust fan turned on to increase ventilation. In addition, the driver can use the climate control system and set the fan at the highest speed possible, while ensuring that the system does not recirculate air. The driver's window can also be opened to increase airflow.[9]

Public Transportation Buses

Similar to school buses, options available include two hatches on the roof, passenger windows, the driver window, and the climate control system. Additionally, public transportation buses have two sets of doors that open and an HVAC system.

Windows and hatches can be opened. The climate control system can be set to the highest fan speed and set so that the system does not recirculate air. The HVAC system can be upgraded to use MERV-13 filters, and both doors can be opened at every stop, regardless of whether passengers are boarding or disembarking through that door. Using a barrier for the driver combined with the climate control system fan can reduce the driver's exposure to bioaerosols from the passengers.[10]

Motor Coach Buses

Coach buses can present a high risk of transmission because typical passenger travel could extend for longer periods.[11] Unlike school buses, the coach buses have an HVAC system, but these buses often do not have operable windows.

The hatches can be opened, the driver's window can be opened, the HVAC system turned on to not recirculate air, and the climate control system fan run and set to not recirculate air. The HVAC system can be upgraded to use MERV-13 filters.

Trains

Acceptable air quality on trains is provided using an HVAC system with no natural ventilation options available. Systems must be run continuously, sometimes referred to as ventilation mode, and supply

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[8] US EPA, "Air Cleaners, HVAC Filters, and Coronavirus (COVID-19)," United States Environmental Protection Agency. Accessed: Feb. 21, 2024. [Online]. Available: https://www.epa.gov/coronavirus/air-cleaners-hvac-filters-and-coronavirus-covid-19

[9] M. Van Dyke, B. King, E. Esswein, J. Adgate, M. Dally, and M. Kosnett, "Investigating dilution ventilation control strategies in a modern U.S. school bus in the context of the COVID-19 pandemic," *J Occup Environ Hyg*, vol. 19, no. 5, pp. 271–280, 2022, doi: 10.1080/15459624.2022.2050739.

[10] N. J. Edwards et al., "Reducing COVID-19 Airborne Transmission Risks on Public Transportation Buses: An Empirical Study on Aerosol Dispersion and Control," *medRxiv*, p. 2021.02.25.21252220, Mar. 2021, doi: 10.1101/2021.02.25.21252220.

[11] X. Yang et al., "Transmission of pathogen-laden expiratory droplets in a coach bus," *J Hazard Mater*, vol. 397, p. 122609, Oct. 2020, doi: 10.1016/J.JHAZMAT.2020.122609.

outdoor air while passengers are onboard. HVAC systems can be upgraded to use MERV-13 filters for recirculated air and not solely outdoor air.

Subways

In subway cars, there is typically little to no access to natural ventilation for passengers. Acceptable air quality is provided through a mechanical ventilation system, with limited options to further improve the system. The HVAC system can be upgraded so that the recirculated air is filtered with MERV-13 filters.

Airplanes

ANSI/ASHRAE Standard 161-2018, Air Quality within Commercial Aircraft, specifies a minimum of 7.1 litres/second per person of supply air in flight and recommends 9.4 litres per second per person of total supply air. Supplied air is typically 50% outdoor air and 50% recirculated air that has been filtered with a HEPA filter.[12] Air is supplied from the ceiling and returns by the passenger's feet, which creates vertical airflow that increases air distribution effectiveness.

Personal air outlets (gaspers) are located above the passengers, and each one can increase the supply airflow rate by approximately 1 litre/second. Although there might be a slight benefit in using them, it is not significant.[13] When the aircraft engine is not running, ventilation can be provided through a ground cart or using the auxiliary power unit. Airlines should ensure that the ventilation system is always running whenever passengers are onboard, even during boarding and deplaning.

Conclusion

Overall, improving indoor air quality in transportation vessels is crucial for reducing the risk of airborne disease transmission. Implementing effective ventilation strategies, such as maintaining continuous HVAC operation, upgrading filters to higher efficiency options like MERV-13 or HEPA, and maximizing natural ventilation, when possible, can significantly enhance air quality. In vehicles with limited ventilation, like school buses or motor coaches, minimizing recirculation and using exhaust fans and window openings are essential. For systems like airplanes and trains, ensuring proper air supply and filtration is key. These measures across various transportation modes will help create safer and healthier environments for passengers.

[12] International Air Transport Association, "Low on Board Transmission Risk." Accessed: Feb. 21, 2024. [Online]. Available: https://www.iata.org/en/youandiata/travelers/health/low-risk-transmission/

[13] ASHRAE, "ASHRAE EPIDEMIC TASK FORCE," Nov. 2020, Accessed: May 29, 2024. [Online]. Available: www.ashrae.org.covid19

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