International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(Review Article)

Check for updates

Mitigating the spread of emerging and resurgent airborne infectious diseases: Strategies, challenges and future directions

Franklin Akwasi Adjei [1,*] and Augustine Afriyie [2]

[1] *College of Health Sciences, Division of Kinesiology and Health, University of Wyoming, United States of America.*
[2] *College of Basic and Applied Sciences, Middle Tennessee State University, United States of America.*

International Journal of Science and Research Archive, 2025, 16(01), 1443-1451

Publication history: Received on 13 June 2025; revised on 18 July 2025; accepted on 21 July 2025

Article DOI: https://doi.org/10.30574/ijsra.2025.16.1.2188

Abstract

The resurgence of airborne infectious diseases, including measles, COVID-19, and tuberculosis, has raised significant public health concerns globally. These diseases, transmitted through respiratory droplets or aerosols, present unique challenges, particularly in indoor spaces where vulnerable populations are at greater risk. This article provides a comprehensive review of current strategies to mitigate airborne infectious diseases, examining both emerging and resurgent threats. It categorizes and evaluates interventions such as source control (masking and physical distancing), ventilation improvements, and air filtration, assessing their real-world effectiveness in reducing infection rates and enhancing indoor air quality. The article also explores the synergistic effects of combining multiple strategies and addresses implementation challenges related to cost, compliance, and infrastructure. It highlights gaps in current knowledge, particularly regarding the integration of advanced technologies and the long-term impact of combined interventions. The review concludes by proposing future research directions aimed at refining mitigation strategies, optimizing ventilation and air purification systems, and integrating artificial intelligence to enhance public health responses. Ultimately, it advocates for a holistic, evidence-based approach to improve public health preparedness against airborne infectious diseases.

Keywords: Airborne infectious diseases; Measles; COVID-19; Tuberculosis; Source control; Ventilation strategies; Air filtration; Public health; Disease mitigation; Indoor air quality; Infection control; Air purification; Artificial intelligence

1. Introduction

Recently, airborne infectious diseases have become an increasing threat to public health, with both new and evolving illnesses raising global concerns. Measles, once nearly eliminated in the U.S., has recently seen a concerning resurgence, with outbreaks across multiple states highlighting the ongoing vulnerability of populations to vaccine-preventable airborne diseases. Similarly, COVID-19, caused by the SARS-CoV-2 virus, continues to evolve, with new variants spreading rapidly and causing waves of infections. In addition to these well-known pathogens, diseases like tuberculosis and seasonal influenza have also reemerged, emphasizing the persistent danger of airborne illnesses. These diseases mainly spread through respiratory droplets or aerosols, making indoor spaces such as schools, healthcare facilities, and public transportation particularly susceptible to outbreaks. The complexity and ability of these pathogens to mutate underline the need for strong and adaptable strategies to reduce transmission and protect vulnerable groups. As global travel increases, the challenge of controlling airborne infectious diseases remains significant, underscoring the importance of ongoing assessment and improvement of prevention efforts.

* Corresponding author: Franklin Akwasi Adjei

1.1. Purpose and Scope of the Article

This article offers a detailed review of strategies to reduce airborne infectious diseases amid the resurgence of illnesses like measles, COVID-19, and other emerging pathogens. It aims to categorize and assess these strategies based on how well they lower infection rates and improve air quality in public spaces. The focus is on evaluating their real-world effectiveness and addressing challenges such as costs, compliance, and infrastructure limits that prevent widespread use. Additionally, the article examines whether combining multiple strategies creates synergistic effects, potentially leading to better control of airborne diseases. By synthesizing existing knowledge, it highlights research gaps and provides recommendations for future studies and policies to enhance mitigation efforts. Ultimately, it promotes a comprehensive approach that integrates scientific evidence with practical public health measures to build more resilient and effective responses to emerging and resurging airborne infectious threats.

2. Airborne Infectious Disease Prevention and Mitigation Strategies

People living in densely populated areas face a higher risk of contracting infectious diseases, such as influenza, measles, and SARS-CoV-2. The risk of infection varies depending on the exposure circumstances and can occur through multiple routes. Preventing and controlling airborne infectious diseases is a complex, multidisciplinary challenge that involves various scientific and engineering fields, including the study of built environments, to protect populations from all potential exposure pathways. Numerous efforts have been made to curb the current pandemic through measures such as quarantine, social distancing, disinfection, mask-wearing, proper ventilation, air purification, and filtration, as essential precautions against airborne infections.

There are many potential sites for spreading airborne infectious agents in indoor spaces, including sick/infected persons, the presence of contaminated indoor air, and the threat of recirculated contaminated air through Heating, ventilation, and air conditioning (HVAC) systems [1]. Much effort has been made to eliminate or keep airborne infectious diseases at low levels to prevent the spread of infection. Technically advanced interventions include pressurization, dilution, filtration, purification, and nanotechnology. [2]To prevent the transmission of viruses, it is recommended that liquid droplets and airborne particles be minimized from indoor spaces by increasing ventilation rates, reducing the recirculation of stale, contaminated air, implementing natural ventilation, personalized ventilation, personalized exhaust systems, humidity regulation, and temperature control. [3,4].

Multiple strategies exist at different scales to reduce disease risk in a building, involving interventions at various levels including building design, equipment usage, occupant behavior changes, and policy measures to support these efforts. The next subsection focuses on airborne infectious disease prevention and mitigation strategies: source control, ventilation, air purification/filtration, and other methods to improve indoor air quality and lower disease transmission risk.

2.1. Source Control Strategies (Masking and Physical Distancing)

Source control strategies try to prevent or limit airborne infectious transmissions with the source itself. Various source control strategies include the use of masks, detection, tracking, and isolating infected persons, as well as avoiding the spread and intake of the virus from its carriers to healthy individuals. The first way to control the spread of airborne infectious diseases is by limiting sick persons' connections by physical separation and other interventions and lowering the transmission probability per contact. [5]. Masks are physical barriers used to prevent/control the spread of infectious agents known as bioaerosols from an infected person to the immediate environment and to prevent the inhalation of these infected aerosols by a healthy individual. Masks are intended to reduce the spread of infectious droplets, which is especially critical for asymptomatic patients unaware of their infectious status. Masks have been shown to minimize the inhalation of infected bioaerosols by filtering the air at the source. [6–8].

Social distancing is another source control strategy for mitigating airborne infectious diseases [9,10]. Research [11], has noted that reducing indoor airborne transmission of respiratory infectious diseases would be achieved by enforcing intermittent gaps in inbuilt space occupancy and recommending that all users walk out of the space periodically (taking short breaks). According to a study [12], the combination of proper social distancing (which can be achieved by reducing occupancy) and high ventilation effectiveness could significantly reduce the transmission risk of coronavirus. It was found that a reduction of 50% occupancy density can result in a reduction in infection rate by 20–40%. Quanta generation is an individual's emission of infectious materials [13–15]. The infection risk is linked to the quanta generation rate, suggesting that source control measures are sensible for reducing infection risk during the pandemic. The chance of indirect infection is also notably lowered by wearing masks, with FFP2/N95 (and FFP3/N99) masks being especially effective against aerosol transmission. Cross-sectional studies show that communities with high reported mask-wearing and physical distancing have the highest predicted probability of transmission control [16]. Other measures, such as ventilation or mobile air purifiers, do not prevent the need to wear masks during the pandemic. Instead, they provide an additional layer of protection against indirect infections. Moreover, research shows that masks' efficacy is non-linear and highly dependent on the airborne viral concentration in the room air [17]. Masks, however, must always be worn correctly, completely covering the mouth and nose and fitting as tightly as possible.

Several studies have tried to determine a safe physical distance to avoid direct transmission, based on how far droplets from coughing can travel. These studies show that environmental factors, especially airspeed and direction, can greatly affect how far respiratory droplets can go travel. [18]. Using a modified version of the Wells-Riley model, Sun and Zhai [12] determined that the minimum safe distance for regular social activities indoors was 1.6–3 m; however, they note that occupant density, ventilation rate and effectiveness, and exposure time have a marked influence on infection probability. Concluding such findings in the outdoor setting is challenging [19].

Physical distancing should be maintained indoors and outdoors to reduce the risks of direct transmission. Distancing, ventilation, and air purification measures cannot replace the primary function of wearing face masks (i.e., source control).

2.2. Ventilation Improvement Strategies

Improving the dilution rate of airborne infectious agents is the primary approach to minimizing an individual's vulnerability or exposure to dangerous microorganisms in a confined place. Ventilation is an engineering strategy that provides air movement that contributes to diluting and dispersing airborne infectious diseases [20,21]. Ventilation, or replacing contaminated indoor air with clean outdoor air, is crucial in mitigating airborne infectious diseases ([20,22–25]

The Wells– Riley equation is the basis for ventilation [26–28]. According to the equation, the air change rate is inversely proportional to the concentration of indoor pollutants. Therefore, adequate fresh air ventilation with an acceptable outdoor air exchange rate will help mitigate the transmission of infectious agents [23,24] The World Health Organization is the global agency responsible for providing health-related guidance.

There are three main categories of ventilation: mechanical, natural, and hybrid. Mechanical ventilation uses mechanical equipment like fans or blowers to ventilate the spaces and typically requires electricity. On the other hand, natural ventilation is achieved without mechanical equipment[29–31]). Many buildings are mechanically ventilated, which increases energy consumption. The third type of ventilation is hybrid or mixed mode, incorporating mechanical and natural ventilation. In hybrid ventilation, equipment such as fans and blowers is used when natural ventilation is not feasible [32].

Ventilation is a straightforward method that can help enhance other airborne infectious disease strategies. Research has shown that ventilation enhances vaccination efforts. [33]. A study showed that ventilation has a similar transmission risk-reducing effect as vaccine coverage of 50–60% [34]. A natural means of ventilation is opening windows, an efficient ventilation technique that will reduce the risk of infectious disease transmission; opening them more expansively and for an extended period is preferable. When a window is opened in the main wind direction of the region and a window in the opposite facade, it allows air to travel through the indoor spaces more efficiently [35–37]. The predominant airflow direction inside the room must be from the fresh zone to the less fresh zones or contaminated areas; if not, strategies such as the stack effect, installation of wall/window air extractors, or whirlybirds should be adopted to rectify the airflow direction. High-intensity natural ventilation has been found effective in reducing the viral transmission risk. If the weather conditions permit, it can be achieved by opening windows/doors on opposite facades. [22,33,35] analyzed the efficacy of various control strategies in terms of their risk-reducing potential; the findings demonstrated that outdoor air ventilation reduces infection risk.

ASHRAE [38,39] recommended that minimum ventilation rates might not be adequate to reduce the transmission of infectious agents such as the SARS-CoV-2 virus in enclosed settings. HVAC systems should not be used as per the usual operation schedule. They must be revised accordingly, as there is a risk of increased air contamination in indoor spaces due to the ongoing pandemic. They also recommend keeping the ventilation system on for as long as possible. Additionally, more efforts should be geared toward outdoor air ventilation, although there is caution against using it in highly polluted areas. When ventilation systems are used according to demand, demand-controlled ventilation should also be turned off.

Displacement ventilation (mechanical/natural) is a feasible option for negative pressure isolation chambers in hospitals, which commonly use mixing ventilation. Negative pressure is created in the occupied zone, which brings clean air in from the outside, and positive pressure is created towards the roof, which expels the hot, stale air [40–42] The hospitals' isolation chambers, when compared to corridor spaces and neighboring spaces, must use negative differential pressure, quickly expelling room air to the exterior of the building to keep aerosolized viruses (from isolation spaces) out of circulation from shared spaces[24,43]. However, the problem is that the same negative pressure might unintentionally expose room occupants to airborne infections from corridor area inhabitants. To counter this, a study suggested adding an anteroom to isolation rooms that would operate as a separator between common areas and isolated spaces, reducing disease transmission.

Demand control ventilation can be a useful energy-efficient feature in non-pandemic settings. However, in an airborne pandemic or a threat of airborne infectious diseases, establishments should make every effort to maintain the air as clean as possible. Demand-controlled ventilation limits air supply-based CO_2 setpoint during occupied hours to save energy. However, this energy-saving is at the cost of reduced ventilation, which is not recommended in the event of airborne infectious diseases. In light of this, demand-control ventilation should be turned off to improve ventilation rates [44,45]. If demand-control ventilation reduces the virus's transmission risk, the CO2 concentration setpoint should be lowered enough to maintain adequate indoor ventilation.

In essence, high-intensity fresh air ventilation, avoiding recirculation of contaminated air, must be used to minimize the spread of infectious diseases. This effectively and swiftly removes the virus particles and keeps indoor aerosol concentrations as low as possible. Natural and mechanical ventilation strategies have the potential to reduce airborne transmission if designed and operated efficiently [46]. Hence, existing international and national standards and guidelines should be revised to incorporate the threat of airborne infectious agents. Country, region, and context-specific space ventilation standards must be formulated according to the various variables acting upon these spaces. Also, technologies and various building system components must be optimized to maintain energy efficiency parameters while incorporating these changes.

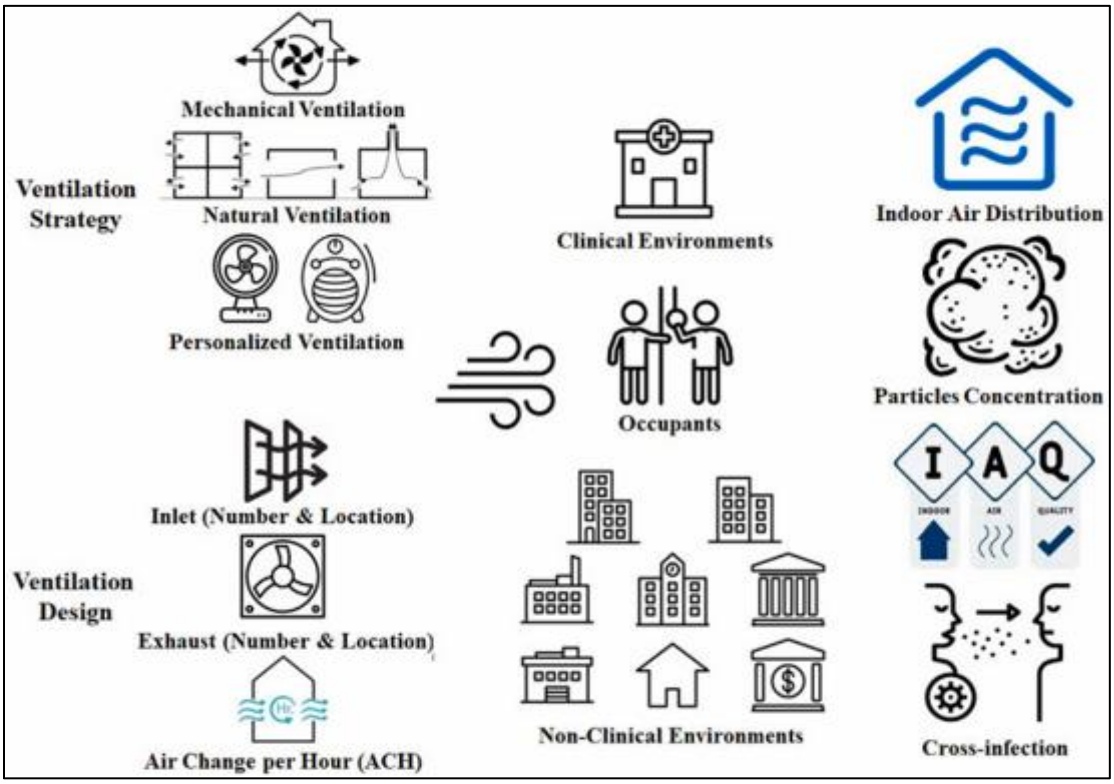

Figure 1 Ventilation strategies [47]

2.3. Air Filtration and Purification

Research has shown that filtering or purifying the air with various filters and purifiers in indoor spaces lowers the viral load, minimizing the chances of virus transmission [48–50]. Air filters remove infectious agents through inertial collision, diffusion, gravitational effect, and electrostatic attraction. In places where natural ventilation faces critical challenges, the intake of air can be filtered using air filters to remove contaminants. Then, it can be supplied into indoor spaces. Air filtration or purification systems can be provided in the ducts of air conditioning systems, inside the room, and for the occupant zones to functionally minimize the risk of the virus transmission through aerosols [48–50].

ASHRAE [39] have recommended various measures to curb airborne infectious aerosol exposure. The measures include the application of mechanical air filters, MERV and HEPA filters, Electronic Air Cleaners, Gas-Phase Air cleaners, Ultraviolet disinfection devices, etc., in places with high outdoor pollution, such as metropolitan cities, where natural ventilation is problematic and infeasible. Incoming outdoor air can be screened with High-Efficiency Particulate Air (HEPA) filters to remove infectious agents and contaminants [48,49,51]. HEPA filters effectively reduce bioaerosols since they remove at least 99.95% of the particles with a diameter of 0.3 μm and more significant fractions while only causing low-pressure drops. HEPA filters remove particles through three mechanisms: interception and diffusion [52]. Research [52]has shown that a HEPA filter will entirely capture the direct application of DNA aerosols, but as the droplets move through the BSC, there can be up to 0.01% contamination. Electrostatic precipitators (ESPs) are air filtering devices that use a small industrial fan to move the air through the filter. The electrically charged solid and liquid particles in the air are collected on a grounded plate within the device. ESP has a lower pressure drop when compared to other mechanical air filtering devices with comparable efficiencies and hence can be used as an alternative to HEPA filters [53].

Air filtration and purification effectively reduce airborne virus transmission indoors, especially when providing sufficient fresh air ventilation is difficult. Factors like cost, pressure drop, lifespan, and energy use are key considerations when choosing a filtration medium. Balancing these factors and selecting devices based on the contaminant type and size can improve occupant health. Conducting a cost-benefit analysis helps ensure a comprehensive evaluation of filter performance when selecting the right filter medium.

2.4. Other Approaches for Airborne Infectious Disease Mitigation

Ultraviolet (UV) light exposure is a direct antimicrobial approach, and its effectiveness against various strains of airborne viruses has been established for a long time. The most employed type of UV light for germicidal applications is a low-pressure mercury-vapor arc lamp, emitting around 254 nm; more recently, xenon lamp technology has been used, which emits a broad UV spectrum6. However, while these lamps can be used to disinfect unoccupied spaces, direct exposure to conventional germicidal UV lamps in occupied public spaces is not possible since direct exposure to these germicidal lamp wavelengths can be a health hazard, both to the skin and eye [54,55].

Ultraviolet irradiation has been employed in operating rooms for over half a century to reduce airborne bacterial contamination. Safety considerations have limited its intensity to 25–30 μw cm^{-2}; at this level, no more than a fourfold reduction has resulted. In recent studies, intensities up to 300 μw cm^{-2} have been used without untoward effects, and, at the highest intensity, contamination as low as that obtained with ultraclean air ventilation systems was obtained [56].

Far-UVC light is anticipated to have about the same anti-microbial properties as conventional germicidal UV light but without producing the corresponding health effects. Should this be the case, far-UVC light has the potential to be used in occupied public settings to prevent the airborne person-to-person transmission of pathogens such as coronaviruses [57].

Very low doses of far-UVC light efficiently kill airborne human coronaviruses carried by aerosols. A 1.2 to 1.7 mJ/cm2 dose of 222-nm light inactivates 99.9% of the airborne human coronavirus tested from both genera beta and alpha, respectively. As all human coronaviruses have similar genomic size, a key determinant of radiation sensitivity27, far-UVC light will likely show comparable inactivation efficiency against other human coronaviruses, including SARS-CoV-2. The results of [57] suggest that using continuous low-dose-rate far-UVC light in occupied indoor public locations such as hospitals, vehicles, restaurants, airports, and schools is a safe and inexpensive tool to reduce the spread of airborne-mediated viruses.

Ultraviolet germicidal irradiation (UVGI) has been used to “scrub” the air in healthcare facilities and laboratories for decades. UVGI is known to be efficacious to varying degrees in controlling the circulation of airborne infectious particles. Approximately 60% of all UVGI air disinfection systems are installed in healthcare facilities [58]. This equates to 41% in hospitals and 19% in clinics [58]

Personalized ventilation (PV) that delivers clean air directly to a patient's breathing zone, thereby improving the ventilation efficiency for individual patients in the same room, may enable optimal infection control. Botanical biofilters are activated systems that allow air movement through the plant growth substrate to increase the rate at which the indoor atmospheric environment is exposed to the plant-substrate system components active in air pollutant removal [23,59].

Personal ventilation may better protect occupants against airborne pathogens than total-volume room-air replacement [60]. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) position document on airborne infectious diseases also recommends PV and other ventilation strategies (such as dilution ventilation, local exhaust, and source control ventilation) as effective measures to control and prevent disease transmission. This proposed strategy supports evidence that personal ventilation combined with mixing ventilation (MV) can provide better protection against airborne infection than mixing ventilation alone.

Generally, adopting effective ventilation strategies that dilute indoor contaminants and regulate airflow patterns to minimize occupants' contact with bioaerosols is effective in reducing transmission. Different ventilation methods should be chosen based on indoor and outdoor conditions. Air filtration and purification/disinfection techniques have been shown to decrease airborne viral loads. Air purifiers with disinfection features like UV are especially effective against infectious agents. Recirculating HVAC systems in buildings must incorporate efficient air filtration methods to limit the spread of infectious particles indoors.

3. Future Research Directions

The current standards, techniques, and systems emphasize ventilation systems, mainly focusing on thermal comfort parameters. Additionally, HVAC systems are intended to regulate the balance of fresh outdoor air and recirculated indoor air to ensure proper ventilation and energy efficiency. Due to energy considerations, ventilation systems may provide only the minimum required ventilation, which might not be enough to reduce the spread of airborne infectious agents [46,59]. Additionally, occupants' behavior in a building affects ventilation and energy efficiency [46]. Considering this, ventilation systems should be designed with the behavior of occupants of the building in mind and should be designed to maximize ventilation, protecting both people and energy efficiency. Therefore, the threat of future airborne diseases stresses the need for a new ventilation strategy or system for building spaces to mitigate airborne infectious diseases without compromising occupant comfort. and energy efficiency parameters. Also, studies must explore and assess the cost-based analysis for various building typologies. Although numerous studies have been conducted in offices, schools, and other public spaces, there is a scarcity of research assessing multiple strategies to mitigate airborne infectious diseases in mechanically ventilated residential spaces.

In the age of artificial intelligence's resurgence, researchers need to combine machine learning, deep learning, and artificial intelligence with intelligent systems to mitigate airborne infectious diseases in built spaces [61]. However, the implementation/validation of these strategies in actual buildings has not been sufficiently explored. Research on the effectiveness of partition walls, temporary screens, and other partition strategies in reducing virus transmission is limited. There is a lack of studies identifying the best materials, sizes, orientations, and combinations with other IAQ improvement measures. Empirical evidence on how factors like weather and socio-demographic characteristics influence airborne transmission is scarce. Additionally, studies analyzing gender, age, and subgroup differences, along with their association with airborne infectious disease spread and mortality rates, are also limited. Most research focuses on viral airborne diseases, while other causes, such as bacteria and fungi, need further examination.

4. Conclusion

Airborne infectious components remain infectious for hours and can increase incidence and spread rapidly. Other environmental factors, such as temperature and humidity, significantly influence indoor viral transmissions. However, most existing air conditioning and mechanical ventilation systems have limitations in simultaneously maintaining thermal comfort, indoor air quality, and energy balance. Therefore, there is a need for a novel ventilation strategy or system for building spaces to reduce airborne infectious diseases without compromising thermal comfort and energy efficiency standards. This review paper explores strategies and methods to mitigate the transmission of airborne infectious agents, guide post-pandemic building operations, and minimize the transmission of contagious agents. The identified strategies are context-specific; their application and effectiveness vary depending on circumstances and environmental conditions. Public health professionals, along with architects, computational modelers, and civil engineers, should select, integrate, and implement various sustainable strategies to protect individuals against indoor airborne infectious agents.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Nair AN, Anand P, George A, Mondal N. A review of strategies and their effectiveness in reducing indoor airborne transmission and improving indoor air quality. Environ Res. 2022 Oct 1; 213:113579.

[2] Megahed NA, Ghoneim EM. Indoor Air Quality: Rethinking rules of building design strategies in post-pandemic architecture. Environ Res. 2021 Feb; 193:110471.

[3] Qian H, Zheng X. Ventilation control for airborne transmission of human exhaled bio-aerosols in buildings. J Thorac Dis. 2018 Jul;10(Suppl 19):S2295–304.

[4] Sloan Brittain O, Wood H, Kumar P. Prioritising indoor air quality in building design can mitigate future airborne viral outbreaks. Cities Health. 2021 Jul 21;5(sup1):S162–5.

[5] Howard J, Huang A, Li Z, Tufekci Z, Zdimal V, van der Westhuizen HM, et al. An evidence review of face masks against COVID-19. Proc Natl Acad Sci. 2021 Jan 26;118(4):e2014564118.

[6] Eikenberry SE, Mancuso M, Iboi E, Phan T, Eikenberry K, Kuang Y, et al. To mask or not to mask: Modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic. Infect Dis Model. 2020 Jan 1;5:293–308.

[7] MacIntyre CR, Cauchemez S, Dwyer DE, Seale H, Cheung P, Browne G, et al. Face Mask Use and Control of Respiratory Virus Transmission in Households. Emerg Infect Dis. 2009 Feb;15(2):233–41.

[8] Matuschek C, Moll F, Fangerau H, Fischer JC, Zänker K, van Griensven M, et al. Face masks: benefits and risks during the COVID-19 crisis. Eur J Med Res. 2020 Aug 12;25(1):32.

[9] Block P, Hoffman M, Raabe IJ, Dowd JB, Rahal C, Kashyap R, et al. Social network-based distancing strategies to flatten the COVID-19 curve in a post-lockdown world. Nat Hum Behav. 2020 Jun;4(6):588–96.

[10] Prem K, Liu Y, Russell TW, Kucharski AJ, Eggo RM, Davies N, et al. The effect of control strategies to reduce social mixing on outcomes of the COVID-19 epidemic in Wuhan, China: a modelling study. Lancet Public Health. 2020 May 1;5(5):e261–70.

[11] Melikov AK. COVID-19: Reduction of airborne transmission needs paradigm shift in ventilation. Build Environ. 2020 Dec;186:107336.

[12] Sun C, Zhai Z. The efficacy of social distance and ventilation effectiveness in preventing COVID-19 transmission. Sustain Cities Soc. 2020 Nov;62:102390.

[13] Azimi P, Keshavarz Z, Cedeno Laurent JG, Allen JG. Estimating the nationwide transmission risk of measles in US schools and impacts of vaccination and supplemental infection control strategies. BMC Infect Dis. 2020 Jul 11;20(1):497.

[14] Beggs CB, Shepherd SJ, Kerr KG. Potential for airborne transmission of infection in the waiting areas of healthcare premises: stochastic analysis using a Monte Carlo model. BMC Infect Dis. 2010 Aug 20;10(1):247.

[15] Zhou J, Wei J, Choy KT, Sia SF, Rowlands DK, Yu D, et al. Defining the sizes of airborne particles that mediate influenza transmission in ferrets. Proc Natl Acad Sci. 2018 Mar 6;115(10):E2386–92.

[16] Ueki H, Furusawa Y, Iwatsuki-Horimoto K, Imai M, Kabata H, Nishimura H, et al. Effectiveness of Face Masks in Preventing Airborne Transmission of SARS-CoV-2. mSphere [Internet]. 2020 Oct 21 [cited 2025 Jan 14]; Available from: https://journals.asm.org/doi/10.1128/msphere.00637-20

[17] Eikenberry SE, Mancuso M, Iboi E, Phan T, Eikenberry K, Kuang Y, et al. To mask or not to mask: Modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic. Infect Dis Model. 2020 Jan 1;5:293–308.

[18] Bhaganagar K, Bhimireddy S. Local atmospheric factors that enhance air-borne dispersion of coronavirus - High-fidelity numerical simulation of COVID19 case study in real-time. Environ Res. 2020 Dec;191:110170.

[19] Timmons S, Belton CA, Robertson DA, Barjaková M, Lavin C, Julienne H. Is it riskier to meet 100 people outdoors or 14 people indoors? Comparing public and expert perceptions of COVID-19 risk. 2020;

[20] Melikov AK. COVID-19: Reduction of airborne transmission needs paradigm shift in ventilation. Build Environ. 2020 Dec 1;186:107336.

[21] Nembhard MD, Burton DJ, Cohen JM. Ventilation use in nonmedical settings during COVID-19: Cleaning protocol, maintenance, and recommendations. Toxicol Ind Health. 2020 Sep;36(9):644–53.

[22] Lipinski T, Ahmad D, Serey N, Jouhara H. Review of ventilation strategies to reduce the risk of disease transmission in high occupancy buildings. Int J Thermofluids. 2020 Nov 1;7–8:100045.

[23] Nielsen PV. Control of airborne infectious diseases in ventilated spaces. J R Soc Interface [Internet]. 2009 Dec 6 [cited 2025 Jan 15]; Available from: https://royalsocietypublishing.org/doi/10.1098/rsif.2009.0228.focus

[24] Qian H, Zheng X. Ventilation control for airborne transmission of human exhaled bio-aerosols in buildings. J Thorac Dis. 2018 Jul;10(Suppl 19):S2295–304.

[25] Widder SH, Haselbach L. Relationship among Concentrations of Indoor Air Contaminants, Their Sources, and Different Mitigation Strategies on Indoor Air Quality. Sustainability. 2017 Jul;9(7):1149.

[26] Noakes CJ, Sleigh PA. Applying the Wells-Riley equation to the risk of airborne infection in hospital environments: The importance of stochastic and proximity effects. 2008;

[27] Sze To GN, Chao CYH. Review and comparison between the Wells–Riley and dose-response approaches to risk assessment of infectious respiratory diseases. Indoor Air. 2010 Feb;20(1):2–16.

[28] Zhang S, Lin Z. Dilution-based Evaluation of Airborne Infection Risk - Thorough Expansion of Wells-Riley Model [Internet]. medRxiv; 2020 [cited 2025 Jan 15]. p. 2020.10.03.20206391. Available from: https://www.medrxiv.org/content/10.1101/2020.10.03.20206391v1

[29] Ali AAA, Milad GN, Aly HM. Effect of Natural Ventilation and Wind Direction on the Thermal Performance of a Building Ceiling. In: Goswami DY, Zhao Y, editors. Proceedings of ISES World Congress 2007 (Vol I – Vol V). Berlin, Heidelberg: Springer; 2009. p. 436–40.

[30] Fordham M. Natural ventilation. Renew Energy. 2000 Jan 1;19(1):17–37.

[31] Ogoli DM. Performance of Natural Ventilation in Deep-plan Educational Buildings: Case Study. ARCC Conf Repos [Internet]. 2013 [cited 2025 Jan 15]; Available from: https://arcc-repository.org/index.php/repository/article/view/215

[32] Hamdy M, Mauro GM. Optimizing Hybrid Ventilation Control Strategies Toward Zero-Cooling Energy Building. Front Built Environ [Internet]. 2019 Aug 8 [cited 2025 Jan 15];5. Available from: https://www.frontiersin.org/journals/built-environment/articles/10.3389/fbuil.2019.00097/full

[33] Melikov AK. COVID-19: Reduction of airborne transmission needs paradigm shift in ventilation. Build Environ. 2020 Dec;186:107336.

[34] Smieszek T, Pouwels KB, Dolk FCK, Smith DRM, Hopkins S, Sharland M, et al. Potential for reducing inappropriate antibiotic prescribing in English primary care. J Antimicrob Chemother. 2018 Feb 1;73(suppl_2):ii36–43.

[35] Fanti MP, Mangini AM, Roccotelli M, Iannone F, Rinaldi A. A natural ventilation control in buildings based on co-simulation architecture and Particle Swarm Optimization. In: 2016 IEEE International Conference on Systems, Man, and Cybernetics (SMC) [Internet]. 2016 [cited 2025 Jan 15]. p. 002621–6. Available from: https://ieeexplore.ieee.org/document/7844634

[36] Kleiven T. Natural Ventilation in Buildings. 2003;(7242).

[37] Liddament M, Axley J, Heiselberg P, Li Y, Stathopoulos T. Achieving Natural and Hybrid Ventilation in Practice. Int J Vent. 2006;5(1):115–30.

[38] CDC. About Ventilation and Respiratory Viruses [Internet]. Ventilation. 2020 [cited 2025 Jan 15]. Available from: https://www.cdc.gov/niosh/ventilation/about/index.html

[39] Van Doremalen N, Bushmaker T, Morris DH, Holbrook MG, Gamble A, Williamson BN, et al. Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1. N Engl J Med. 2020 Apr 16;382(16):1564–7.

[40] Cho S, Im P, Haberl JS. Literature Review of Displacement Ventilation [Internet]. Energy Systems Laboratory, Texas A&M University; 2005 May [cited 2025 Jan 15]. Available from: https://hdl.handle.net/1969.1/2845

[41] Mundt E. Displacement ventilation systems—Convection flows and temperature gradients. Build Environ. 1995 Jan 1;30(1):129–33.

[42] Yuan X, Chen Q, Glicksman LR. A Critical Review of Displacement Ventilation. 1998;

[43] Wei J, Li Y. Airborne spread of infectious agents in the indoor environment. Am J Infect Control. 2016 Sep 2;44(9 Suppl):S102-108.

[44] Acker B, Wymelenberg KVD. Demand control ventilation: lessons from the field- how to avoid common problems. ASHRAE Trans. 2011 Jan 1;117(1):502–9.

[45] Sowa J, Mijakowski M. Humidity-Sensitive, Demand-Controlled Ventilation Applied to Multiunit Residential Building—Performance and Energy Consumption in Dfb Continental Climate. Energies. 2020 Jan;13(24):6669.

[46] Chenari B, Dias Carrilho J, Gameiro da Silva M. Towards sustainable, energy-efficient and healthy ventilation strategies in buildings: A review. Renew Sustain Energy Rev. 2016 Jun 1;59:1426–47.

[47] Izadyar N, Miller W. Ventilation strategies and design impacts on indoor airborne transmission: A review. Build Environ. 2022 Jun 15;218:109158.

[48] Chen F, Hong X. Design of Intelligent Air Purifier and Indoor Environment Improvement System. IOP Conf Ser Earth Environ Sci. 2019 Jul 1;300(3):032102.

[49] Liu G, Xiao M, Zhang X, Gal C, Chen X, Liu L, et al. A review of air filtration technologies for sustainable and healthy building ventilation. Sustain Cities Soc. 2017 Jul 1;32:375–96.

[50] Vijayan VK, Paramesh H, Salvi SS, Dalal AAK. Enhancing indoor air quality –The air filter advantage. Lung India Off Organ Indian Chest Soc. 2015;32(5):473–9.

[51] Wang Y, Wang W, Zhang Z, Zhou P, Jiang H. Design and Research of Intelligent Air Purifier System. In: 2020 IEEE International Conference on Mechatronics and Automation (ICMA) [Internet]. 2020 [cited 2025 Jan 15]. p. 1822–6. Available from: https://ieeexplore.ieee.org/document/9233851

[52] F H, RundellClark, ThibeaultRobert, GhidoniDaniel, MagoonDaniel, NguyenTrinh, et al. The Effectiveness of HEPA Filters on DNA. Appl Biosaf [Internet]. 2018 Jun 1 [cited 2025 Jan 15]; Available from: https://www.liebertpub.com/doi/10.1177/1535676018766080

[53] Afshari A, Ekberg L, Forejt L, Mo J, Rahimi S, Siegel J, et al. Electrostatic Precipitators as an Indoor Air Cleaner—A Literature Review. Sustainability. 2020 Jan;12(21):8774.

[54] Setlow RB, Grist E, Thompson K, Woodhead AD. Wavelengths effective in induction of malignant melanoma. Proc Natl Acad Sci. 1993 Jul 15;90(14):6666–70.

[55] Zaffina S, Camisa V, Lembo M, Vinci MR, Tucci MG, Borra M, et al. Accidental Exposure to UV Radiation Produced by Germicidal Lamp: Case Report and Risk Assessment. 2012 [cited 2025 Jan 15]; Available from: https://onlinelibrary.wiley.com/doi/10.1111/j.1751-1097.2012.01151.x

[56] Lidwell OM. Ultraviolet radiation and the control of airborne contamination in the operating room. J Hosp Infect. 1994 Dec 1;28(4):245–8.

[57] Buonanno M, Welch D, Shuryak I, Brenner DJ. Far-UVC light (222 nm) efficiently and safely inactivates airborne human coronaviruses. Sci Rep. 2020 Jun 24;10(1):10285.

[58] Memarzadeh F, Olmsted RN, Bartley JM. Applications of ultraviolet germicidal irradiation disinfection in health care facilities: Effective adjunct, but not stand-alone technology. Am J Infect Control. 2010 Jun;38(5):S13–24.

[59] Sandberg M, Kabanshi A, Wigö H. Is building ventilation a process of diluting contaminants or delivering clean air? Indoor Built Environ [Internet]. 2019 Mar 20 [cited 2025 Jan 15]; Available from: https://journals.sagepub.com/doi/10.1177/1420326X19837340

[60] Bolashikov ZD, Melikov AK. Methods for air cleaning and protection of building occupants from airborne pathogens. Build Environ. 2009 Jul 1;44(7):1378–85.

[61] Adjei F. Artificial Intelligence and Machine Learning in Environmental Health Science: A Review of Emerging Applications. Commun Phys Sci 2025 125 1480-1492. 2025;