EDITORIAL

Infectious disease transmission from bioaerosols

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The emergence of the COVID-19 pandemic has exposed the need to better understand bioaerosol exposure as a vector in infectious disease transmission. While a wealth of new research has provided key findings specific to the spread of the pandemic, the continued and regular emergence of infectious diseases (e.g., seasonal influenza, SARS, MERS, avian flu, swine flu, COVID-19, etc.) highlights the role bioaerosols are expected to play in future public health threats. Personal and public policy responses to the COVID-19 pandemic have produced an interesting dichotomy. At the onset, many individuals implemented numerous, and often drastic and disruptive, lifestyle modifications to limit exposure to, and transmission of, the virus. Yet, as the pandemic continued it became evident that translating research results to actionable public policy guidelines that promoted protective health decisions, while simultaneously achieving compliance, was a significant challenge. Unfortunately, this shortcoming persists.

The 9 articles contained in this Bioaerosol Disease Transmission collection focus on the nexus between research findings related to bioaerosol transmission and exposure and actionable recommendations, guidelines, and policies that are focused on health-protective decision-making. In this collection we include research findings that identify the physical underpinnings of virus transmission and exposure as well as broader perspectives that inform the implementation of public protective measures. The articles are broadly divided into two categories: (1) respiratory aerosol production and transmission; and (2) mitigation approaches for minimizing transmission risk. We hope that the collection provides insights that are relevant beyond the current pandemic.

RESPIRATORY AEROSOL PRODUCTION, TRANSMISSION, AND INFECTIVITY

Aerosol transmission is governed by the quantity and size distribution of particles produced during respiratory activities, the human expiratory velocity that expels them into the surrounding, the environmental conditions that influence near field and far field concentrations, the infectivity of the particles, and the location and activities of the receptors. The emission rates and size distributions of particles produced during speech is explored in Ahmed et al., "Characterizing respiratory aerosol emissions during sustained phonation," (https://doi.org/10.1038/s41370-022-00430-z), while the importance of flow pulsatility on the expiratory velocity fields and particle transport is investigated in Morris et al., "Influence of expiratory flow pulsatility on the effectiveness of a surgical mask," (https://doi.org/10.1038/s41370-022-00416-x).

In addition to quantifying particle production and transmission, elucidating the infectivity of emitted respiratory particles and the resultant infection risk is an important, but challenging, undertaking. These topics are addressed by Santarpia et al., "The size and culturability of patient-generated SARS-CoV-2 aerosol," (https://doi.org/10.1038/s41370-021-00376-8) and Vecherin et al., "Assessment of the COVID-19 infection risk at a workplace through stochastic micro exposure modeling," (https://doi.org/10.1038/s41370-022-00411-2).

Finally, environmental conditions such as ambient air velocity, humidity, and the size and geometry of occupied indoor spaces can produce drastic spatial and temporal variations in particle concentrations, and hence, infection risk. The influence of humidity, which has not been as well explored in the literature as other factors, is considered in Keetels et al., "Associated evidence for the potential of humidification as a non-pharmaceutical intervention for influenza and SARS-CoV-2 transmission," (JESEE-21-3781).

MITIGATION APPROACHES FOR MINIMIZING TRANSMISSION RISK

Together with advances in vaccines, therapeutics and diagnostics, application of these science-based mitigation methods can greatly reduce risks from airborne diseases. The primary mitigation approaches for minimizing bioaerosol exposure and disease transmission include masks for faces and instruments, physical distancing, physical barriers (for reduction of near-field respiratory droplets), increased ventilation (10 L/s per person recommended for reducing the risk of airborne infectious disease transmission in buildings), increased filtration, portable air cleaners, germicidal UV systems, and sensors for informing occupants and building HVAC systems (e.g., carbon dioxide as an indication of whether outdoor air ventilation is sufficient for building occupancy).

Several of these mitigation approaches are investigated in this collection. The effects and effectiveness of masking are evaluated in Kniesburges et al., "Effects of surgical masks on aerosol dispersion in professional singing," (https://doi.org/10.1038/s41370-021-00385-7) and Wang et al., "Bridge the gap: correlate face mask leakage and facial features with 3D morphable face models," (https://doi.org/10.1038/s41370-021-00399-1). The mitigation of exposure via cleaning is explored in Shaughnessy et al., "Effects of classroom cleaning on student health: a longitudinal study," (https://doi.org/10.1038/s41370-022-00427-8). Additionally, as previously discussed, the association between humidity and epidemiological metrics are quantified for periods of influenza and SARS-CoV-2 epidemics since 1995 in Keetels et al., "Associative evidence for the potential of humidification as a non-pharmaceutical intervention for influenza and SARS-CoV-2 transmission," (JESEE-21-3781).

OUTSTANDING QUESTIONS AND FUTURE PERSPECTIVES

Since the emergence of COVID-19, there have been thousands of journal articles published on bioaerosol disease transmission and mitigation. From the scientific perspective, we feel there is still

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significant progress that needs to be made in the following areas related to bioaerosol exposure:

a. High-fidelity aerosol and flow transport models that capture the complex physics generated by respiratory activities and that are able to provide information in near real-time for infection risk models.
b. Sensors that are able to detect specific agents or proxies of those agents in real time.
c. Communication to building occupants and building operators that can inform them of exposure and risk in a way that supports decision-making to reduce exposures.
d. Better understanding and application of the connection between personal actions, social interactions and bioaerosol exposure risk.
e. Improved communication and development of common language among exposure scientists, building scientists, epidemiologists and others in the public health and medical communities, and policy makers.

While there are still open scientific questions, we certainly have enough knowledge to implement effective solutions. Morawska et al. (2021) [1] pushed for a stronger connection between our understanding of the mechanisms behind airborne respiratory infection and the way we address the transmission of respiratory infections, consistent with our regulation and mitigation response to water-borne diseases, food safety, and sanitation. Accordingly, multidisciplinary task forces and commissions have developed recommendations to reduce infection risk based on science and understanding of the practice (e.g., ASHRAE [2], Lancet COVID-19 Commission [3]). We hope this collection also contributes to this much needed "paradigm shift".

Finally, public perception of, trust in, and compliance with best practices have presented unanticipated obstacles. Accurate and consistent messaging is paramount as even now, policies and guidelines are continually changing, eroding public trust and resulting in increased mortality rates. To combat this, we need to base our response on actionable scientific findings that will ensure the highest degree of compliance. That is, considerations of both exposure science and social science. Communicating and learning from past mistakes will determine how we respond to future bioaerosol exposure threats that may arise.

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DATA AVAILABILITY

All data contained in this article will be made available upon request.

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COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

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