ME – PhD Thesis Defense

"Insights on the evaporation and precipitation of pathogen-laden respiratory droplets on inanimate surfaces"

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Venue: Online (Click here to join)

ABSTRACT

Disease transmission via fluid ejections from infected individuals is a critical public health concern, particularly in high-risk environments like hospitals, public transport, restaurants, and schools. Respiratory droplets containing pathogens such as viruses and bacteria, once deposited on surfaces, can dry and form fomite deposits, facilitating secondary transmission through contact and ingestion. Understanding the evaporation, fluid flow, and precipitation dynamics of such droplets is crucial, yet the interplay between these factors in protein-salt biofluid droplets, and their collective impact on pathogen distribution and survival across varying environmental and surface conditions, remains underexplored. This thesis investigates the evaporation dynamics, internal fluid flow, and pathogen deposition patterns of surrogate respiratory droplets, made of mucin and NaCl, on different substrates (glass, ceramic, steel, PET). Using virus-emulating particles (VEP) and techniques like fluorescence and SEM imaging, the distribution of these particles in dried deposits is studied. Shadowgraphy and optical microscopy track evaporation and precipitation, while MicroPIV reveals internal flow dynamics. Confocal imaging shows pathogen-like particle distribution, highlighting the influence of interfacial transport processes on fomite formation. All droplets exhibited constant contact radius evaporation mode, with internal flows combining capillary and Marangoni effects, resulting in varied edge deposits. Crystallization patterns differed by substrate, and VEP concentration was highest near the three-phase contact line and crystal surfaces, underscoring the role of interfacial processes in fomite-driven infection, especially during COVID-19. Additionally, this study addresses the under-researched topic of droplet behaviour on inclined surfaces. Surrogate respiratory droplets, doped with 0.86μm bacteria-like particles, were studied on substrates inclined at 0°, 45°, and 90°. Results show significant alterations in evaporation, flow, and crystallization dynamics due to inclination, leading to varied nucleation and crystal growth. Confocal microscopy and optical profiling reveal higher bacterial accumulation at the bottom edge, suggesting increased pathogen survival on inclined fomites. Real bacterium Pseudomonas Aeruginosa (PA) was introduced into respiratory droplets to study pathogen survivability under different environmental conditions. A fivefold difference in PA survivability was observed under varying relative humidity (RH) and temperature conditions, illustrating how fomite-mediated disease transmission may vary by geography. For instance, London's average RH (71%) and temperature (11°C) in 2023 differs significantly from New Delhi's (45% RH, 26°C), suggesting that fomite infection pathways could have demographic dependencies. Lower evaporation rates, particularly under high RH and low temperature, extended crystallization times and reduced internal flows, leading to denser bacterial deposits and enhanced pathogen survivability. Further investigations into the effects of salt and mucin concentrations revealed that elevated mucin increased PA viability tenfold, while salt had minimal impact. Adhesive properties of the deposits were analysed, showing significant pathogen transfer under elevated RH. Klebsiella pneumoniae bacteria also demonstrated unique self-assembly behaviours in evaporating droplets, with a preference for survival in the contact line's "coffee ring" deposits. These insights have critical implications for disease control, influencing sanitization strategies, surface design, and infection prevention efforts.

ABOUT THE SPEAKER

Abdur Rasheed is a PhD candidate in the Mechanical Engineering Department at the Indian Institute of Science, working under the supervision of Prof. Saptarshi Basu. His research focuses on experimental investigations of biofluid droplets on inanimate surfaces. Prior to his PhD, he served as an Assistant Professor in the Department of Aerospace Engineering at SRM Institute of Science and Technology, Chennai. Abdur holds a Master's degree in Aerospace Engineering from the Indian Institute of Technology, Madras, and a Bachelor's degree in Aeronautical Engineering from Hindusthan College of Engineering and Technology, Coimbatore.