A computational fluid dynamics study of the infectiousness decay of droplets propagating pathogens when exposed to evaporation coupled with UVGI

Emmanuel Igumbor[*,a], Mbolahasina Ralijaona[a], Kennedy Otwombe[b,c], Firdaus Nabeemeeah[c], Neil Martinson[c], Pedro Mafa[d], Lerothodi Leeuw[e], Simon Connell[a]

[a]Department of Mechanical Engineering Science, University of Johannesburg, Auckland Park, Johannesburg, South Africa.
[b]Perinatal HIV Research Unit, Chris Hani Baragwanath Academic Hospital, Faculty of Health Sciences, University of the Witwatersrand South Africa
[c]School of Public Health, Faculty of Health Sciences, University of the Witwatersrand South Africa.
[d]Department of Mathematical Sciences, UNISA - ATLAS High Energy Physics Group, University of South Africa, Johannesburg, 1710, South Africa.
[e]Department of Physics and Astronomy, University of the Western Cape, Bellville 7535, Cape Town, South Africa
*elgumuk@gmail.com

Respiratory diseases propagated by droplet-based transmission are serious public health hazard, leading to pandemics, such as Coronavirus outbreak [1]. One engineering intervention used to mitigate the spread of droplet-based transmission pathogens is the ultraviolet germicidal irradiance (UVGI) [2]. The UVGI device has the tendency to disinfect air and surfaces through intense ultraviolet germicidal irradiance, which damages infectious microorganisms [3]. This process coupled with environmental conditions such as temperature and relative humidity help to reduce the spread of aerosol transmission of pathogens [4]. In this study a computational fluid dynamics (CFD) simulation with the combination of parameters describing the humidity and temperature was used to investigate the infectiousness of droplets in a confined room. The droplets were modelled using the discrete phase approach under transient flow conditions. Droplets particles were injected from the inlet at 1.19 ms^{-1} to a fluid domain and allowed to move in the ambient flow, subject to illumination with UVGI. Due to the turbulence effects of the droplets, the general Navier-Stoke equation which deals with viscous flow and turbulence is used. The turbulence is treated with the Shear-Stress Transport (SST) $k-\omega$ model, and the Reynolds stresses are modeled with the Boussinesq hypothesis, the turbulent kinetic energy and the specific dissipation rate transport equations were considered. The trajectories of the droplets were determined by integrating the force balance in the Lagrangian reference frame. The enthalpy, incompressible flow, mass fraction of species and radiation were accounted for in the energy equation. The discrete phase boundary conditions for the inlet and outlet were set to escape, whereas the stationary wall was set to trap with no slip condition allowing droplets to be trapped when they meet the wall. Different models were developed as external scalar user defined function to determine the survival rate and the infectiousness decay of droplets at relative humidity of 25% and temperature of 25°C, during coughing, speaking, and sneezing of a carrier in a confined room. Irrespective of the exhalation events, the survival rate, and the infectiousness of the microorganisms reduced. The infectiousness of droplets significantly reduced when exposed to UVGI coupled evaporation. Therefore, we suggest that the spread of the infectiousness of droplets propagating microorganism in a confined room can be mitigated using our proposed model. Furthermore, we show that our model can be used to validate engineering interventions, form the basis of understanding and controlling infectiousness of droplets propagating pathogens in a confined public health space. including public schools, clinics, and transport systems.

Reference

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