The structure of exhaled droplets and aerosols

Faizan Ahmad
Supervisor: Andrew Bayly

UNIVERSITY OF LEEDS
School of Chemical and Process Engineering

1. Introduction and Motivation

Exhaled aerosols are responsible for the transmission of many respiratory diseases and infections

Droplet size and their suspension time in the ambient environment is dependant on their origin in respiratory tract, i.e bronchiolar, laryngeal or oral[1]

Despite the prevalence of these sub-100 micron particles, **a detailed understanding of composition and structure of these particles is lacking**[2]

Limited characterization is reported

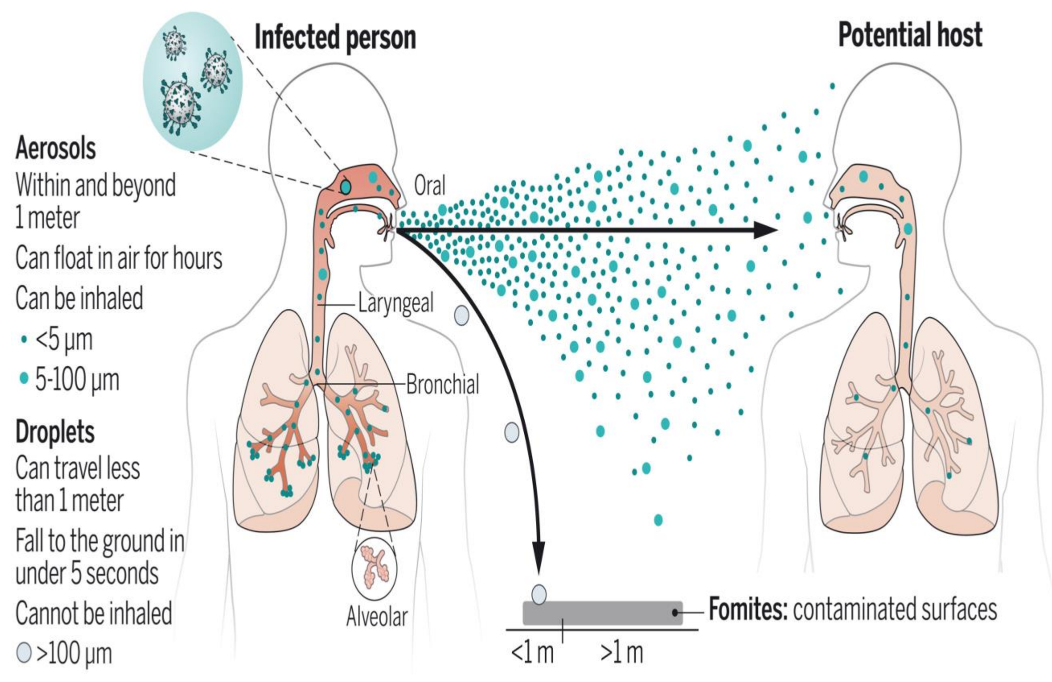


Figure 1. Airborne transmission of respiratory viruses[1]

3. Objectives

1. To develop imaging, analysis and characterisation techniques to study the structure of the dried exhaled particles
2. To characterize the structure and understand the key variables in development of these structures
3. To understand the drying dynamics and structure formation in the synthetic respiratory fluids using single droplet levitation techniques.
4. To understand the impacts of ambient and local environment of the viruses on their viability

2. Background

- The drying dynamics of the exhaled aerosols and the consequent phase change from multi-component solution/suspension to solid particles can lead to particles with internally heterogenous structure[3]
- Liquid-liquid phase separation takes place upon drying[3] forming organic based semi-solid phase states at intermediate relative humidity (RH)[4] and crystallization of salts at lower RH[5]
- The survival of different virus species is varied related to RH but there is a general agreement that the virus exhibit increased survival at both low and very high RH while a decreased survival at intermediate RH levels (mechanism not clear)

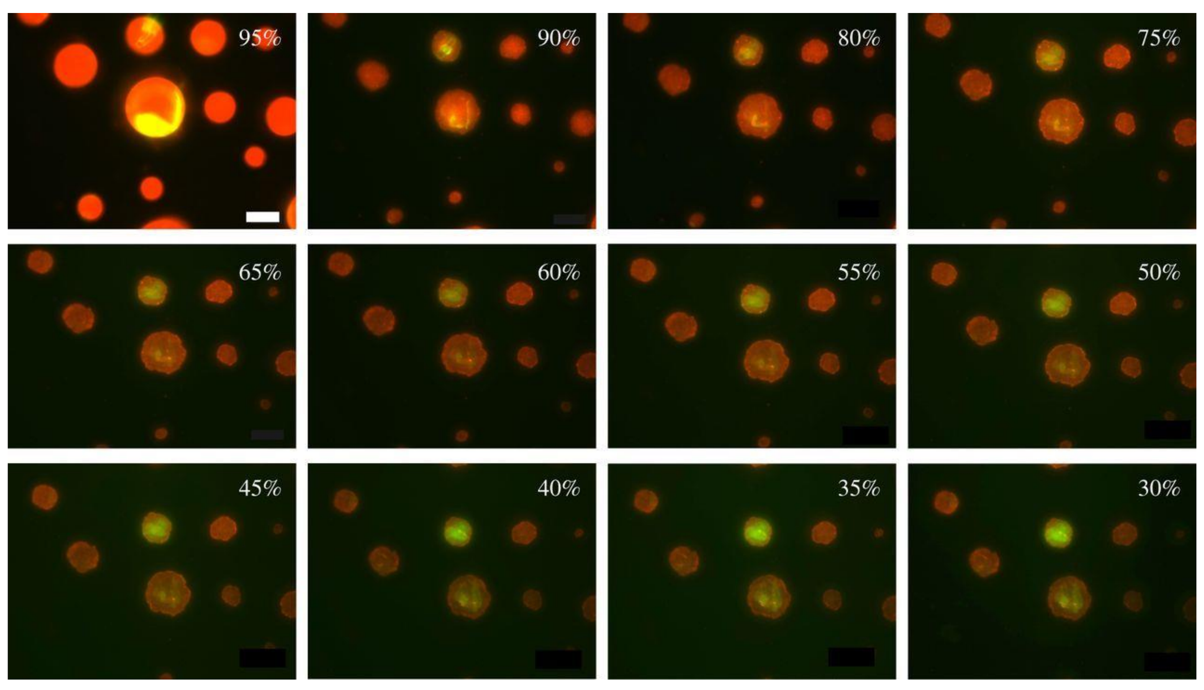


Figure 2. Fluorescence images of synthetic respiratory droplets exposed to decreasing RH. the droplets contained water, NaCl, Mucin, and DPPC[3]

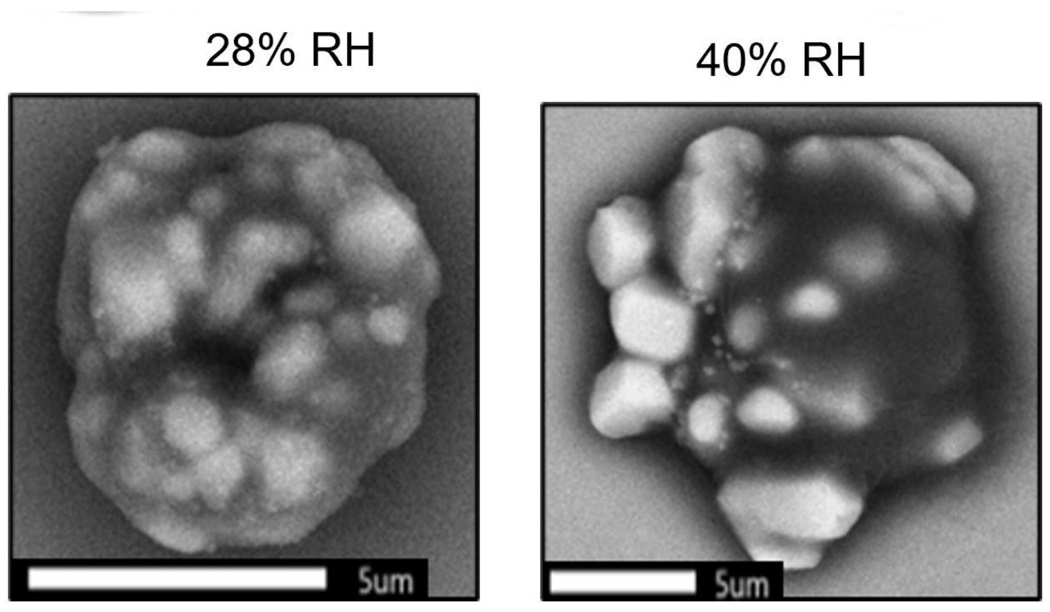


Figure 3. SEM images of droplets effloresced at 28% (left) and 40% RH (right)[5]

5. Responsible Innovation and Impact on Policy

A better understanding of the drying dynamic and subsequent structure formation will help us better understand the trajectories of the droplets both as they are exhaled and inhaled.

The interaction of these droplets with passive surfaces e.g. bouncing, sticking etc. is also dependant on the particle structure, rheo-mechanical properties, surface composition as well as system humidity

The study will provide us support in understanding the survival of pathogens in these particles and may contribute to better policies development to curtail the spread of airborne infections

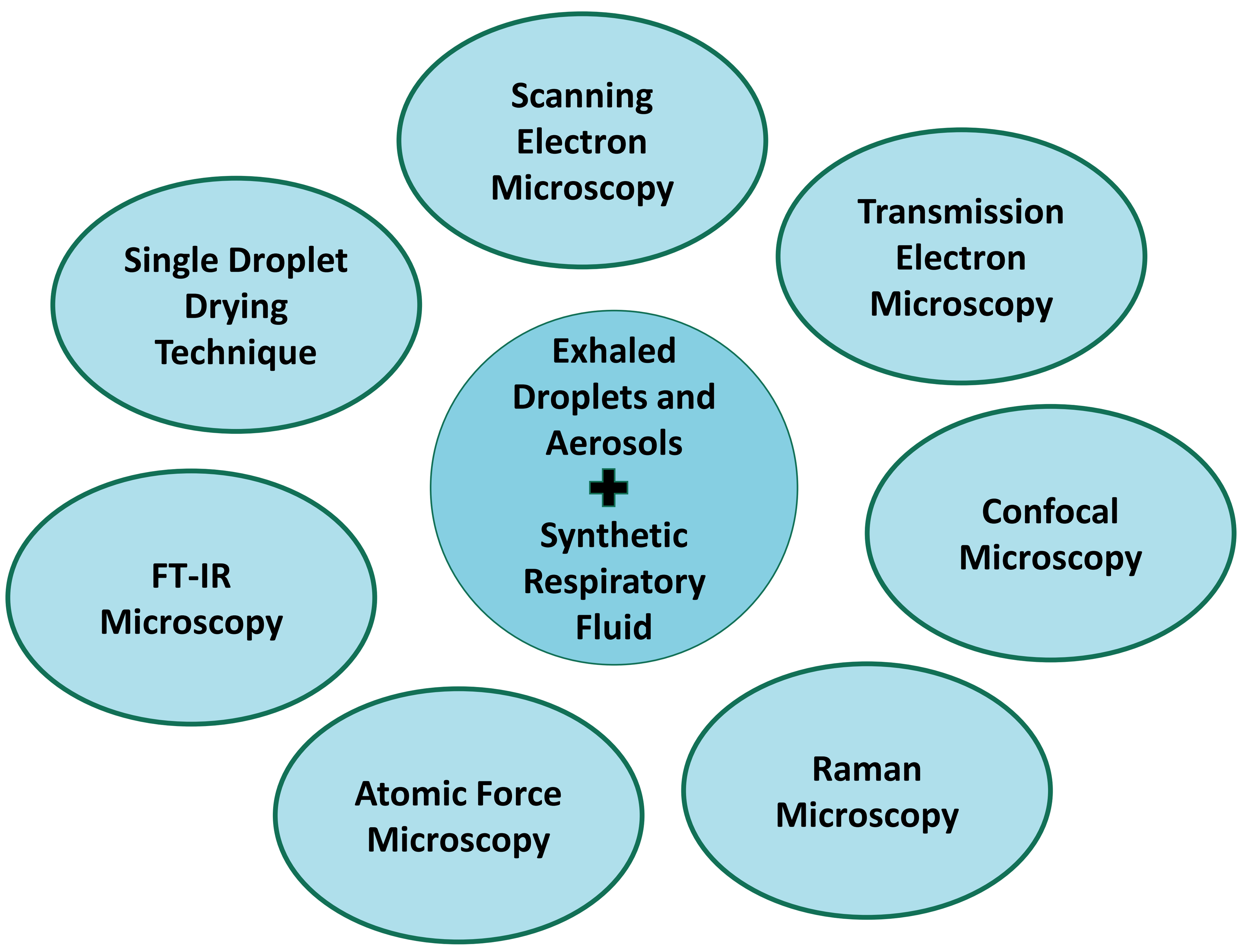
6. Challenges

Mastering a wide range of characterization techniques

Reliable and Reproducible sampling of exhaled droplets avoiding background contamination

4. Characterization Techniques and Methodology

Figure 4. **Summary of characterization and analysis techniques to be used during this project**



Methods:

- Sampling and size classification using a cascade impactor
- Single droplet drying technique for synthetic respiratory fluid
- Addition of surrogate viruses to synthetic respiratory fluid for their characterization

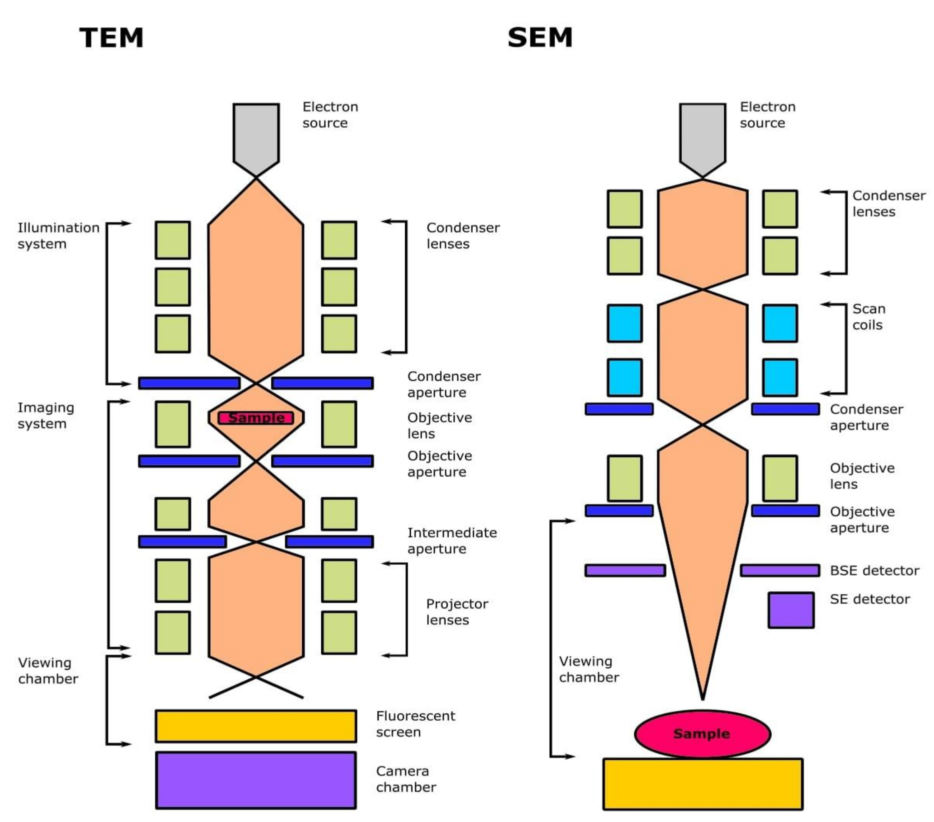


Figure 5. schematic of SEM and TEM microscopy[6]

Key Questions to Answer:

- Crystalline vs non-crystalline
- Chemical species present
- Description of basic structure
- Structure as a function of size
- Heterogeneity of particle structures of samples from one person
- Heterogeneity of particle structures of samples between people
- Assess whether synthetic respiratory fluids are representative
- Assessment of drying dynamics and phase changes
- Imaging viruses in synthetic respiratory fluid droplets

7. References

1. Wang, C. C., et al. (2021). "Airborne transmission of respiratory viruses." Science **373**(6558)
2. Poon, W. C., et al. (2020). "Soft matter science and the COVID-19 pandemic." Soft matter **16**(36): 8310-8324.
3. Vejerano, E. P. and L. C. Marr (2018). "Physico-chemical characteristics of evaporating respiratory fluid droplets." Journal of the Royal Society Interface **15**(139)
4. Huynh, E., et al. (2022). "Evidence for a semisolid phase state of aerosols and droplets relevant to the airborne and surface survival of pathogens." Proceedings of the National Academy of Sciences **119**(4)
5. Oswin, H. P., et al. (2022). "The dynamics of SARS-CoV-2 infectivity with changes in aerosol microenvironment." Proceedings of the National Academy of Sciences **119**(27)
6. https://bitesizebio.com/29197/electron-microscopy-techniques/

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