Extracts from the dispersion report

Key conclusions from this review are

- The dispersion of virus is due to a complex interaction between people either generating or interacting with virus particles and conditions defined by the local environment. This includes the layout of the space and conditions including air movements and ventilation rates, temperature and humidity...
- Evidence from studies evaluating the physics of aerosol dispersion suggest that particles released from a cough or similar could travel much further than 2m, potentially up to 7-8m. Aerosol from environmental sources released in large quantities can travel further still under certain wind conditions...In many environments dilution by the airflow will mean that the risk of significant transfer of virus over large distances will be limited, however this risk has not been clearly quantified.
- There is limited conclusive evidence as to where transmission takes place, however one study from China indicates that it is very likely that the majority of transmission is in indoor environments.
- There is a challenge to relate physical models to actual infection risk, as the data on viral load released by people and remaining in the environment is very limited, and knowledge of infectious dose for different exposure routes is unknown.
- A key next step would be to identify specific scenarios of priority interest and convene an appropriate expert group to develop a strategy for modelling each one, to ensure models produce outputs that are relevant. This will most likely be engineers/mathematical modellers working with clinical, virology, public health and statistical experts, as well as the people who manage the particular environments of interest. Priority interest could be established by examining person density and frequency of visits for different environments, together with an initial assessment of local conditions (e.g. ventilation) to give a risk score that could be used to warrant deeper investigation.

[1]. This paper focuses on aerosol dispersal and environmental spread of pathogens, identifying evidence of relevance to the SARS-COV-2 virus, particularly in relation to the current measures on social distancing and evidence on transmission risk in different indoor and outdoor environments. [Severe acute respiratory syndrome coronavirus 2 (SARS-COV-2) is the strain of coronavirus that causes coronavirus disease 2019 (COVID-19)].

[3]. SAGE should note that *this is not a comprehensive literature review. We summarise some of the key knowledge and papers.*

[5]. Critical to understanding aerosol dispersion is particle size. Particles are referred to by their diameter. The SARS-COV-2 virus is around 0.06-0.14µm (60-140nm) in diameter. Respirable particles are those below 10µm in diameter which have a probability of being inhaled into deep lung. Particles up to 20 µm can reach the thorax, and up to 100µm can be inhaled and impact in the nose and mouth. A human hair is approximately 60µm and below 40µm is unlikely to be visible to the naked eye. The majority of particles of respiratory interest are not visible.

[6]. In medical literature airborne infection normally refers to infection via very small pathogen carrying particles that are 5µm or less in diameter; these are sometimes referred to as droplet nuclei. Those greater than 5- 10 µm are normally referred to as respiratory droplets. The term aerosol is used by some to only refer to droplet nuclei, while others will

use it to describe a wider range of particles. In this document we use the term aerosol as an overarching term to describe respiratory particles across the whole size range of interest.

[7]. It is well recognised that normal respiratory tract activities such as breathing, talking and singing, as well as coughing and sneezing, generate aerosol particles in a range of sizes from 0.01 to more than 500µm in diameter. It is not clear which is the dominant size range, however the majority of recent studies using optical methods for particle counting suggest most particles are below 10µm.

[9]. No conclusive expired breath data exists yet for COVID-19...

[14]. Very large droplets (greater than 800µm), behave ballistically and can travel more than 2m when released forcefully (e.g. in a cough) simply due to their large size and momentum. In still air settling time for small individual particles is governed by fluid dynamics principles (Stokes law) and depends on their size and physical properties; a 2 particle would typically take 4.5 hours to fall 2m while a 10µm particle would fall the same distance in 11min. While this is widely used in evaluating aerosol risk and suggests larger particles fall quickly, reality is much more complex.

[16]. Air, even in indoor environments, is not still - the movement of air in indoor environments is easily enough to maintain a 10µm particle airborne and transport it with air movements caused by ventilation flows or other movements (e.g. people walking, doors opening). Imaging of human cough aerosols and a controlled laboratory study show complex behaviour where aerosol particles travel in a turbulent cloud or plume and are influenced by buoyancy in the environment. This enables the aerosol to travel a bigger distance together in air than may be expected, with distances of up to 7-8m predicted in indoor conditions.

[18]. While it is not clear how well the SARS-COV-2 virus survives in the air in real environments, a controlled laboratory study has shown it to be stable in aerosol for more than 3 hours, with a half-life of over 1 hour

[19]. Evidence of air contamination comes from a small number of studies conducted in hospital environments...

[24, 25]. Aerosol deposition is known to be a route to surface contamination for many pathogens. Studies in controlled chamber and healthcare environments demonstrate bacterial deposition onto surfaces, but data on particle size is not measurable...The small number of studies to date suggests that aerosol deposition of the SARS-COV-2 virus onto surfaces is happening.

[28]. Exposure to aerosol particles depends on physical location with respect to the source, its speed of release (cough higher than breathing) and the size of the particles, as well as the environmental conditions. Conventional thinking is that people less than 1-2m away will be exposed through deposition of larger particles onto mucous membranes, while those further away could inhale the fine aerosol particles. The importance of these two mechanisms is dependent on the disease. Current scientific opinion from world experts in environmental transmission of disease suggests that this distinction may be too simple and could be overlooking routes for exposure.

[29]. Although close range exposure is widely thought to be dominated by droplets, laboratory and modelling studies examining exposure (1-2m) to different sized particles suggests that inhalation exposure to fine aerosols (airborne risk) could be a more significant part of transmission than the direct deposition of droplets onto mucous membranes. This may be significant for the PPE requirements of those in close proximity to infected people and for Aerosol Generating Procedures in clinical environments. The mathematical model in

while not validated with humans (would be very hard to do) enables a method for estimating the relative importance of the droplet deposition and inhalation routes for different distances between people.

[31]. While very large ballistic droplets (>800µm) can potentially travel further than 2m, they will only expose someone directly if they land on mucous membranes on the face...

[32]. Exposure to aerosols below 10µm diameter for those greater than 2m away will be dominated by the airflow conditions in the environment. While there will be some deposition of particles resulting in contact transmission risk, exposure through inhalation is likely to be the dominate risk, and their dispersion can be predicted with airflow models...

[34]. There is good evidence from infection data with other diseases that some people can be "super spreaders" producing a significantly higher infectious aerosol load than others and resulting in high transmission rates...

[35]. There is emerging evidence for super spreaders in the COVID-19 pandemic (e.g. *Boston conference outbreak, Skagit Valley Chorale outbreak, outbreaks associated with religious meetings in France and South Korea) which potentially point to airborne transmission or significant aerosol deposition. However to date these do not appear to have had investigation of the environment in any detail*. [Note: the Skagit experience has now been reported **Hamner L, Dubbel P, Capron I, et al.** ***High SARS-CoV-2 Attack Rate Following Exposure at a Choir Practice — Skagit County, Washington, March 2020***. **MMWR Morb Mortal Wkly Rep 2020;69:606–610**].