BOHS British Occupational Hygiene Society

The Chartered Society for Worker Health Protection

How We Can "Avoid Close Contact" and Stay Safe During the COVID 19 Pandemic

by Dr Mark Piney

All work is completed by Dr Mark Piney and does not necessarily reflect the views of the Society

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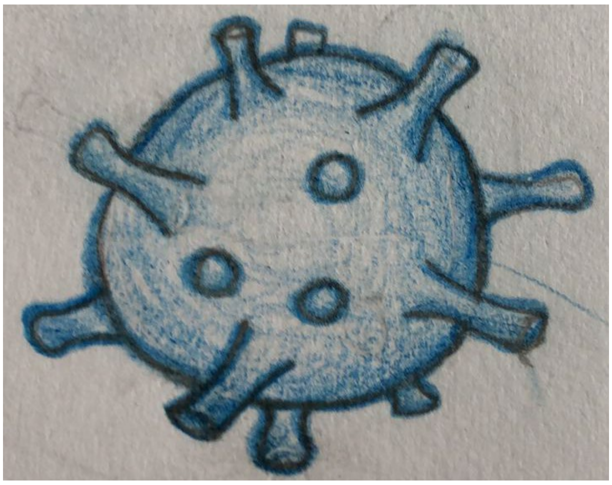
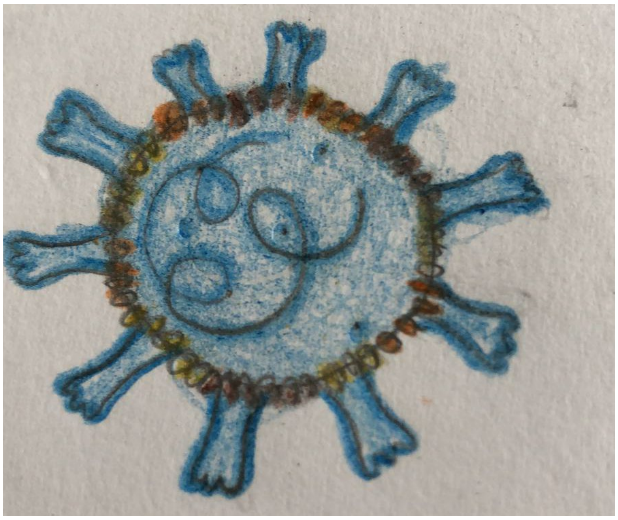
Monday 11th January 2021





2D and 3D virus drawings – Emma Lucor.

What do we know about COVID-19?

1. Exposure to airborne SARs-COV-2[2] is the main way COVID-19 is transmitted
2. People indoors, close together, not wearing masks, in poorly ventilated spaces can be at high risk of overexposure to airborne SARs-COV-2 viruses
3. People outdoors are at much lower risk because the fresh air dilutes and disperses of airborne SARs-COV-2 virus
4. Skin hygiene is important but not as much as controlling exposure to airborne SARs-COV-2 viruses

5. Therefore:

a. Good ventilation
b. Keeping a reasonable physical distance
c. Avoiding over-crowding
d. Wearing a face mask

Are highly likely to prevent SARs-COV-2 being transmitted

These Basic Notes explain some of the detail of how this all works, and how we can stay safe. See also the Government's latest guidance[3]

Good luck.

[1] *"What we do know is that the way to control this virus is the same whatever variant. It simply will not spread if we avoid close contact with others"* Yvonne Doyle (Medical Director at Public Health England, 21st December 2020) **link** These Notes are about defininig what *"close contact"* means in practice and the exposure control measures needed to *"avoid"* it

[2] The virus that causes COVID-19

[3] Appendix 1 *Meeting with others safely (social distancing)* Coronavirus (COVID-19): Meeting with others safely (social distancing) - GOV.UK (www.gov.uk) (Note- Rules in other parts of the UK may vary)

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Summary Points

3D virus drawing – Léa Lucor

Viruses are small and delicate

1. Viruses are very small and cannot move by themselves
2. They have to be transported in airborne droplets/particles usually of saliva
3. Exposure can occur in **two** ways:

   i. **Directly** by impact or breathing in airborne droplets/particles – **the main way** (See Summary Point 8)

   ii. **Indirectly** through skin contact with contaminated surfaces and transfer of very high virus skin contamination by accidental touching of mucous membranes e.g. mouth or nose.

4. Viruses are delicate and they don't remain viable for long outside of the body, particularly in daylight and especially on sunny days. A recent US multidisciplinary Workshop[4] quotes the half-life of SARs-COV-2 as being less than 6 minutes in simulated full sunlight. In other conditions half-life can be much longer, perhaps hours in some cases.

Virus *"Minimum infectious Dose"* (MiD)

5. One virus cannot infect you but a small number, called the *"Minimum infectious Dose"* (MiD) **can** under **two** conditions:
   a. The virus particles must arrive at the surface tissue in your body **in numbers greater** than the Minimum infectious Dose (MiD)
   b. The Minimum infectious Dose (MiD) of viruses must arrive **at the same time**
6. For SARs-COV-2 virus (which causes COVID 19 disease) the *"Minimum infectious Dose"* in healthy people is 100 viral particles or more[5].
7. The *"Minimum infectious Dose"* (MiD) of viral particles greatly increases the chances that one virus will get past the multiple barriers to infection in our bodies including our immune defences

How viruses move from one person to another

8. To move from one person to another SARs-COV-2 virus particles must travel in one, or a few, airborne droplets and/or particles to another person and land on a small patch of cells in that person's body. Summary Point 3 makes it clear that this can

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[4] *"Proceedings of a Workshop: Airborne Transmission of SARs-COV-2"* **Link**

[5] The new SARs-COV-2 variant may be more infectious and the MiD is probably about 50% lower

only happen in two ways. The main way (i) Direct Exposure to airborne droplets/particles being sub-divided into **three**:

a. As flying spit droplets (or fomites) - see Figures 1 and 1a (see page 6)
b. In larger inhalable airborne droplets (LADs) (see Figures 1 and 1a)
c. Or if large numbers of smaller airborne droplets (SADs) or small airborne particles (SAPs) arrive in close sequence (Not shown in Figures 1 or 1a)

Airborne droplets and particles

9. Whether viruses are being carried in larger airborne droplets (LADs) or smaller airborne droplets (SADs) they quickly (as the droplet water evaporates) all become small airborne **(dust)?** particles (SAPs)
10. The largest large airborne droplets (LADs) land in your nose, the back of your throat and perhaps a bit further down your windpipe and cause upper respiratory tract infection (Figure 1)
11. Smaller airborne droplets/particles (SADs/SAPs) land anywhere in the respiratory tract (the airways of the lungs) but the bulk land in the lower parts of the respiratory tract.
12. If the numbers of smaller airborne droplets/particles (SAD/SAPs) are large, for instance, in a very poorly ventilated space containing several people, or in a medical setting where huge numbers of SADs and SAPs are generated by what are called Aerosol Generating Processes (AGPs). In these circumstances viral infection can occur anywhere in the respiratory tract including the lowest lung airways

SARs-COV-2 virus spreads like the Common Cold virus

13. Although SARs-COV-2 is far more deadly, particularly to vulnerable people[6], it spreads like the Common Cold (although it is probably not as infectious as the Common Cold).
14. To reduce the spread of SARs-COV-2 (and the Common cold) certain basic precautions are needed to keep any SAR-COV-2 virus exposure below the Minimum infectious Dose (MiD), including:
    a. Muffling sneezes and coughs with a handkerchief or tissue
    b. Keeping a physical distance from other people to allow our breath-air to mix and become diluted in fresh-air
    c. Ventilation in enclosed spaces such as shops or rooms to dilute any SARs-COV-2 virus particle numbers below the Minimum infectious Dose (MiD). Physical distance can be varied depending on ventilation effectiveness
    d. Wearing a face-mask in shops and similar spaces to reduce our breath-air range and maximise SARs-COV-2 dilution
    e. Treating all surfaces as potentially contaminated and washing your hands

Breath-air range and ventilation

[6] For instance, obese people, older people and those with pre-existing health-conditions

15. Airborne droplets and particles (LADs, SADs and SAPs) are carried suspended in our breath-air
16. We emit breath-air in small puffs of limited range (like little low-powered puffing steam engines – see photograph)
17. Once the small puffs of breath-air mix with fresh air airborne SARs-COV-2 virus numbers are taken below the Minimum infectious Dose (MiD). This is particularly true outside and in well-ventilated spaces
18. A critical way that face masks reduce risk is that they turn us from little low-powered puffing steam engines into large gently smoking 'Roman Candles'.

Dramatically positive effect of wearing a face-mask

Small low-powered puffing 'steam engine'

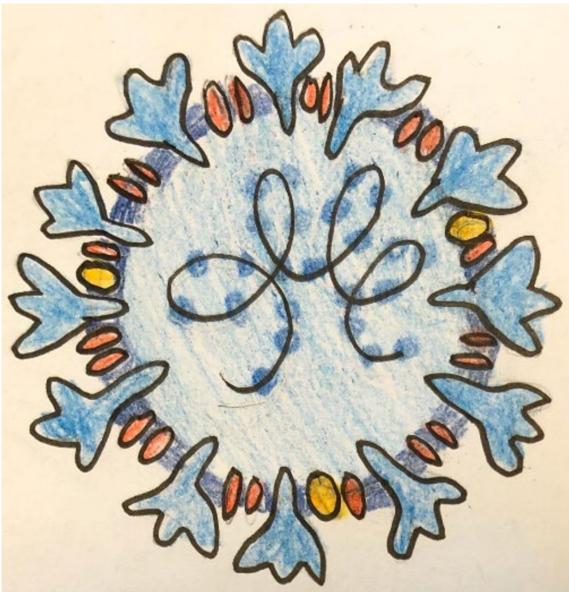
Smaller low-powered wispy puffing 'Roman Candle'

Exposure control measures

A critical part of developing and applying **exposure control measures** is that :

19. They work well enough to effectively control exposure (in this case to SARs-COV-2 virus)
20. They are practical and doable over the long-term
21. They address and answer the question, *"Why am I having to do this?".* This is a perfectly reasonable human question and it needs answering, covering the following issues:

a. If people know how the exposure control measures work, they will have confidence in them and will do what they need to do to protect themselves and others
b. They need to believe that the measures, even if they're a bit of a palaver, will work.
c. It helps to understand some of the details of why and how the measures work so that people can trust and apply them in their own circumstances. This allows some flexibility in what it is possible to do but still keep ourselves and others safe.



2D virus drawing – Léa Lucor

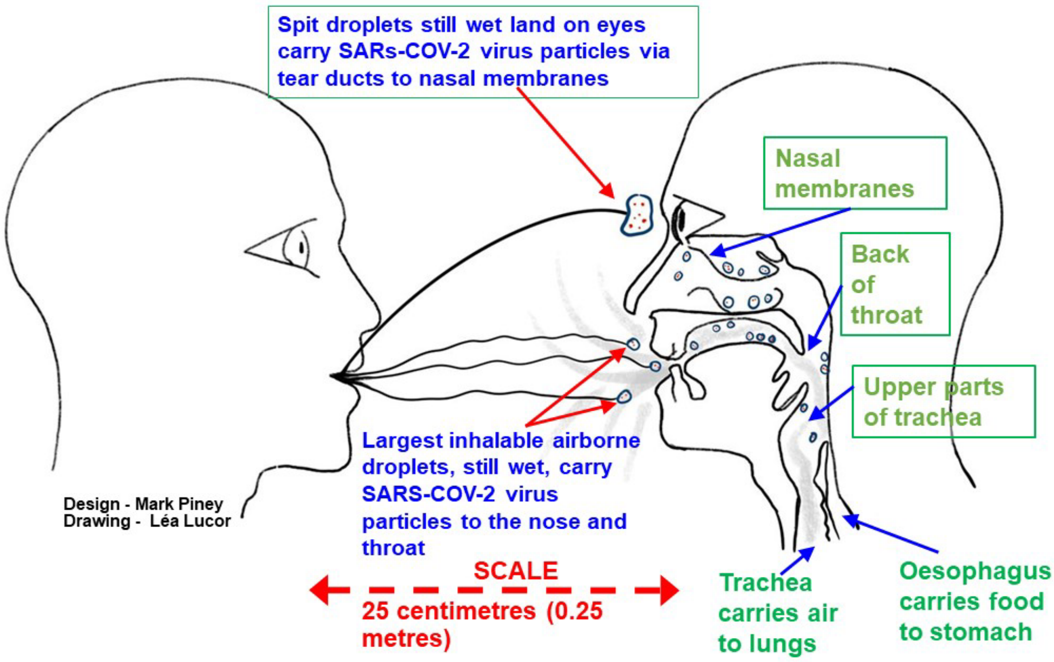


Figure 1 When very close (less than 25 centimetres) and, e.g. talking, wet flying spit droplets can land on someone's face. Singing wet flying spit droplets probably travel further. Whether created by talking or singing the very large flying spit droplets can land on the eyes. From here the SARS-COV-2 viruses can be carried to the nasal membranes via the tear-ducts. The largest (still wet) inhalable airborne droplets can be inhaled and most land on the nasal membranes, back of the throat and top of the trachea (wind-pipe). Figure 1a covers these scenarios in less detail (see below) but reinforces the critical point that being physically close, talking, not wearing a facemask, is risky.

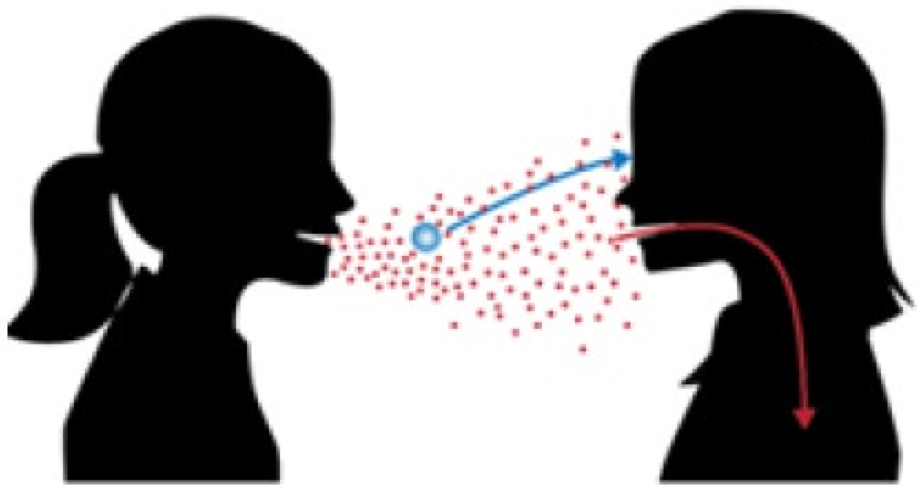


Figure 1a *"Droplets versus aerosols during coughing and talking"* Figure 4 taken from *"Proceedings of a Workshop: Airborne Transmission of SARs-COV-2"* October 2020 **Link**

1.0 *"Basic Notes"* Introduction

1.1 Who is the audience for these Notes?

There are three audiences for these Notes.

1. Those responsible for SARs-COV-2 policy in government and other organisations.
2. Those in management responsible for control of exposure to SARs-COV-2 virus.
3. Interested members of the public.

The British Occupational Hygiene Society (**BOHS**) will illustrate and extend the key messages in these Notes using videos and other material. I've also put these Notes and some comments on my **Website** but please principally go to the Society's Website

1.2 Who am I and what is occupational hygiene?

I am 71 years old. Until I stopped work I was a professional occupational hygienist for 38 years including 22 years working for the UK Health and Safety Executive (HSE) 1989 - 2011. As with any scientific work this isn't a solo effort. I have had lots of help and feedback (see Acknowledgements)

Occupational hygiene is a specialist applied science focussed on exposure to, and control of, chemical, physical and biological health risks at work. The big emphasis is on getting the **exposure control measures**[7] right and maintaining them.

I have won various prizes for the professional quality and impact of my work. See more about the prizes and my career details in the Footnote[8] and associated links.

Much of my professional scientific work involved assessing risks from invisible dusts, vapours and gases, and working with people to develop **exposure control measures** (see Footnote 5).

A critical part of developing and applying **exposure control measures** is that:

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[7] An *"exposure control measure"* is anything that reduces exposure to a contaminant. It could be a process change and behavioural change, and organisational change or the appliance of some form of active control such as ventilation or personal protective equipment (PPE). An *"exposure control measure"* can be anything. Once it's recognised and used then of course it needs to be included in the description of *"exposure control measures"* and maintained.

[8] Retired Member of the British Occupational Hygiene Society (BOHS) Faculty of Occupational Hygiene and retired Health and Safety Executive (HSE) Principal Specialist Inspector in Occupational Hygiene (Details **here** (Linked-In) & **here** See particularly ***Professional*** ***"About"*** and ***"Further Information – HSE Publications"*** and ***Further Information – Some Other Publications***) and ***Further Information – Presentations***). Recently (March - July 2020) Member of BOHS RPE Working Group

1. They work well enough to effectively control exposure (in this case to SARs-COV-2 virus)
2. They are practical and doable over the long-term
3. They address and answer the question *"Why am I having to do this?".* This is a perfectly reasonable human question and it needs answering covering the following issues:
   a. If people know how the exposure control measures work they will have confidence in them and will do what's needed to protect themselves and others.
   b. They need to believe that the measures, even if they're a bit of a palaver, will work.
   c. It helps to understand some of the details of why and how the measures work so that people can trust and apply them in their own circumstances. This allows some flexibility in what's possible to do but still safe.

1.3 *"The dose makes the poison"*

Every day we make judgements based on risk. If you're an adult, you do so almost without thinking. With medicines for instance, we read the instructions and take enough to ease our symptoms but not too much so as to cause bad side-effects.

Two paracetamols (500 milligrams/per tablet) may ease our headache or maybe we need four or six or eight over the day if we have a migraine. If the migraine continues over several days, we may take up to eight paracetamol every day. If you took a week's dose[9] of paracetamol in one go it would be fatal. Spread over a week it isn't[10].

We are **all** following the old rubric that, *"The dose makes the poison"*. We apply the same idea to, for instance, alcoholic drinks and some foods.

The whole of the applied science of occupational hygiene, indeed all medical sciences and the science of toxicology are founded on the same idea, that if exposure to a contaminant/drug is insignificant then it follows that the risk is also insignificant,

"The dose (does) *make the poison".*

The problem with the new virus SARs-COV-2 (which causes Covid 19) is defining what is an insignificant exposure and therefore exactly what exposure controls are needed.

One way is to define insignificant exposure using the concepts of Minimum infection Dose (MiD) and what is understood of how viruses are transmitted from one person to another person. If we can keep exposure to SARs-COV-2 well below the Minimum infectious Dose (MiD) we can stay reasonably safe. Which thinking Such ideas / thoughts leads to a critical point:

[9] For a week the paracetamol dose would be (8 X 7 X 500) 56 tablets or 28 grams of paracetamol.
[10] Although anyone with a migraine which lasts a week would be well advised to see the their GP if they were driven to take this amount of paracetamol

> One SARs-COV-2 virus or even several cannot cause COVID 19 infection i.e. **We can be exposed to some SARS-COV-2 viruses** and yet **not be put at meaningful risk**. One SARs-COV-2 virus particle **does not**, *"…make the poison".*

Late last year (December 2020) it became clear that the SARs-COV-2 virus had mutated and become more infectious[11]

1.4 Sciences and jigsaw puzzles

Different sciences offer different insights and understandings of the world. The applied science of occupational hygiene offers unique, useful, additional understanding of exposure and what can be done to limit the spread of, and danger from SARs-COV-2 virus.

Working out what is going on, and what to do about SARs-COV-2 virus, is a bit like trying to complete a jigsaw puzzle without the picture on the lid as guidance.

Each science helps complete a bit of the puzzle. Over time the picture becomes clearer. The problem, at the moment, is that we don't have a lot of time, the picture is still hazy and yet decisions have to be made. The US National Academies of Sciences, Engineering and Medicine came to the same conclusion in its recent October Workshop:

> *"These questions and more* (about SARs-COV-2 transmission, meant) *that* (the Academies) *convened experts in aerosol science and atmospheric chemistry, building engineering, epidemiology,, environmental health, infectious disease, pulmonary medicine, public health and virology…."* **Link**

1.5 Simple exposure control measures

I've written these Basic Notes because I believe that the SARs-COV-2 virus spread can be well controlled by relatively simple exposure control measures. Many of these are already happening. These Notes reinforces a lot of what is already being done and explains why it works. The exposure control measures will probably work with the new variant of SARs-COV-2 which was first formally identified in November-December 2020.

1.6 How these Notes can help you relax (a bit)

Being on-edge and fearful all the time is wearing. It grinds us down, affects our mental health and may stop us thinking clearly. It is difficult, if not impossible, to stand back and get some perspective when you are chronically frightened.

These Notes explain how and why the SARs-COV-2 exposure control measures work and it is OK to have confidence that they **do** work. Enabling you to do what you need to do to control the COVID 19 risk. To relax and get on with your work and social life. To be a bit less fearful, more relaxed and more social.

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11 Tom Whipple explains (28th December 2020 "Lessons from a global pandemic and a mutating virus" link that the original SARs-COV-2 virus had an R number of about 0.8 (10 infected people could infect another eight people and the COVID-19 numbers would fall) whereas the new variant had a bigger R number of 1.2 (10 people would infect another 12 on average and the COVID-19 numbers would grow)

At a societal level, if we can have confidence in the exposure control measures, we all use, we can then better balance the risks from SARS-COV-2 and other risks we, as a society face. Risks such as delayed cancer operations[12], or joblessness, or lost educational opportunities, or the mental health challenges[13] that chronic fear can cause amongst adults, young people and children.

[12] See, for instance, this recent report by Macmillan cancer charity potential cancer-deaths and suicides link
[13] This is an extract from a FB Message *"…a summer lockdown was bad for people… with mental health, a winter one may well be …worse…The relapse and overdose rate has increased by 30% since March 2020 … the pandemic are especially hard for people with depression* **link** . Resources include - Samaritans **link** and recently set-up Shout **link**.

2.0 Viruses

2.1 How viruses spread

SARS-COV-2 spreads in a similar way to Common Cold viruses
SARs-COV-2 virus, which causes COVID 19 disease, spreads in a similar way to the Common Cold viruses[14]. For most people in the UK nowadays the Common Cold isn't lethal. Whereas SARS-COV-2 virus can kill people, especially the elderly and vulnerable. For some others who are unlucky, it can cause long-term health damage.

Another difference is that, unlike the Common Cold perhaps 40% to 45% of those infected with SARs-COV-2 virus **don't have any tell-tale symptoms** (*"Proceedings of a Workshop: Airborne Transmission of SARs-COV-2"* **Link**) Whereas with the usual Common Cold symptoms are a runny nose and a sore-throat. These are not the standard symptoms of COVID 19 which seems to have a range of early symptoms.

Figure 2 *"Coughs and sneezes spread diseases, trap the germs in your handkerchief"* Tony Hancock The Blood Donor sketch (1961) (See from 09.44 **here**).

Although the health effects and tell-tale symptoms are different, the Common Cold virus and SARS-COV-2 virus routes of exposure and exposure control measures are similar.

Tony Hancock in *"The Blood Donor'* sketch (1961) plays a hopeless buffoon character pompous, sad and almost always wrong. In this sketch[15] he sings a song based on an old government World War 2 poster (Figure 2) ending with *"Trap the Germ in your handkerchief".*

We need to do more than what he sang in the sketch. It's important not so much to just *"Trap the Germs in your Handkerchief"* as do **that plus use other layers of control** such as wearing facemasks, face-shields, physical distancing, good general ventilation etcetera. It is clear that the recent evidence is *"strongly indicative of **airborne transmission**"* (*"Proceedings of a Workshop: Airborne Transmission of SARs-COV-2"* **Link**) Coughs and sneezes **do** spread diseases

2.2. Virus properties and transportation

1. They cannot move by themselves.
2. They can only multiply inside a living cell
3. They are transported to another living cell in bodily fluids such as saliva or blood or

[14] Which include Rhinovirus, Corona virus RSV and parainfluenza are some of them, perhaps 30% of Common cold viruses, are not identified **link** and **link**
[15] But you don't have to sing it to the tune Tony Hancock uses but it fits in with the song lyrics rather well

faeces.
4. Usually they are carried in droplets of saliva
5. They don't survive long on surfaces especially if subject to bright sunlight.
6. They are damaged if the droplets in which they are being transported dry out.
7. All but the largest airborne droplets dry out within a few seconds.

Virus transportation

8. Whether viruses are being carried in larger airborne droplets (LADs) or smaller airborne droplets (SADs) the airborne droplets quickly (as the droplet water evaporates) **all become small airborne *still don't like!* particles** (SAPs)

9. Some, perhaps many, of the viruses in small airborne particles (SAPs) are damaged by drying out and cannot cause infections.

10. Small airborne particles (SAPs) drift suspended in a volume of air just like smoke particles in cloud of cigarette smoke. They move within the air in which they are suspended

11. Viruses are relatively easily destroyed by soapy water or hand-cleanser.

12. Whether by rapid drying of airborne droplets, bright sunlight, or hand cleaning, viruses are relatively easily disabled and made unviable.

Breath-air carries the airborne droplets/particles

13. Airborne droplets and particles LADs, SADs & SAPs are carried suspended in our breath-air

14. We puff out our breath-air like small low-powered puffing steam engines

15. You can measure your own breath-air range (See simple DIY test in Table 1) and see breath-air ranges illustrated in Tables 3a, 3b and 3c.

16. Talking breath-air range (in poor ventilation) is about 50 centimetres

17. All breath-air ranges fall to 1 – 2 centimetres if you wear a face mask – see Tables 3a, 3b and 3c) and Summary Table 4. We become gently smoking 'Roman Candles'.

2.3 Virus infections and Minimum infectious Dose (MiD)

In theory one SARs-COV-2 virus particle could land on any of the 30 trillion[16] cells in our bodies and this could trigger a COVID 19 infection.

In practice this doesn't happen. Viruses, like SARs-COV-2 ,face a succession of bodily barriers. These barriers include:

Physical barriers such as

1. The tears that continually flow over our eyeballs. These wash away and also kill or disable any viruses that land on our eyes
2. Similarly the saliva in our mouths does something similar to tears
3. Our noses and lungs are 'self-cleaning'. They have a thin moving layer of mucous. Any particles (including droplets) that land in our noses or lungs hits the moving

[16] 30,000,000,000,000

mucous layer and is carried, upwards from the lungs and downwards from the nose to the back of the throat where it's swallowed.

Multi-layered immune barriers
The multi-layered, always **ON**, immune system. Which works in all our 30 trillion cells and all our tissues. It learns and remembers. Sometimes it needs 'prompting' with a vaccine.

2.4 The two conditions for SARs-COV-2 virus infections to occur
SARs-COV-2 virus can infect us under two conditions

i The multiple barriers to infection means that in practice, viruses like SARs-COV-2 have to arrive 'mob-handed' to have any chance of causing infection. The minimum number of viruses needed to have a fair chance of causing infection is called the Minimum infectious Dose (MiD). For SARs-COV-2 it's at least 100 virus particles and probably several hundred.

ii There's a **second critical condition** required for infection to occur. The Minimum infectious Dose (MiD) has to land on a very small part of the 'target tissue' at **more-or-less the same time**. Arriving in small numbers in penny-packets, in dribs-and-drabs, will not allow the virus to overcome the body's multiple barriers to infection.

3.0 How is the Minimum infectious Dose (MiD) of SARS-COV-2 virus delivered and where?

3.1 Droplet generation

Airborne droplet creation requires generating mechanisms. In human beings there are four common ones.

1. When our vocal cords vibrate when we talk, sing or shout.
2. When we move our tongue, mouth and lips droplets are created
3. When we cough or sneeze. When this happens air 'explosively' erupts from our lungs and throat and the turbulent 'air-blast' creates droplets.
4. When the small bronchioles leading to the alveoli inflate and collapse on each breath[17]. This action generates ultrafine[18] airborne droplets/particles. These move almost like a gas and hardly settle

The first two mechanisms and the fourth probably account for the reported distribution of airborne droplets/particles **Link**. The vibrating moving lips and tongue generating the larger droplets and the vibrating vocal cords and the collapsing/inflating bronchioles the sub-micrometre (ultrafine) airborne droplets. The tongue, lips and mouth also create the flying spit droplets

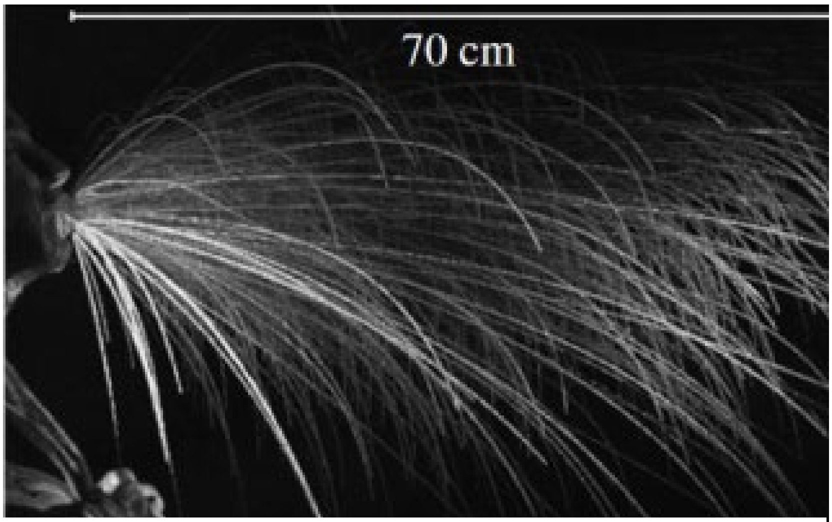


Figure 3 Large flying (projectile) spit droplets fall in a flying (ballistic) curve towards the ground after being emitted from the mouth. Most fall-out of the air close to us. They land still-wet on surfaces including the face of someone very close by – See also Figures 1 & 1a (Taken from Brosseau et al (2020) **link**)

The evidence of SARs-COV-2 viral RNA detected in the breath of people simply breathing is almost certainly the ultrafine droplets/particles. It's worth noting that while SARs-COV-2 RNA is detectable the ultrafine airborne droplets behave almost like a gas and do not easily land on surfaces including the respiratory tract. In the context of smoking they are of interest[19].

Ultrafine airborne particles are unlikely, in most circumstances, to deliver a Minimum infectious Dose (MiD). Although laboured breathing, during for instance running, is highly

[17] See Fennelly June 2020 **here**

[18] Less than a micrometre in aerodynamic diameter

[19] A smoker's breath is full of such ultrafine airborne particles which can be smelt on their breath for sometime after they've stubbed out the cigarette.

likely to create more than just ultrafine airborne particles, runners should pass others at a good physical distance.

3.2 Droplet travel

Flying spit droplet release
Spit droplets created by the movement of the tongue and lips fly out of our mouths and quickly land on nearby surfaces including the face of someone we're talking to, if they are unlucky! (see Figure 1, 1a & 3). The spit droplets lose water as they fly falling through the air. There's enough water in them to mean that they are still wet when they hit nearby skin/surfaces.

3.3 **Airborne droplets travel in the *"breath-air"***

Separate from flying spit-droplets all other droplets/particles are airborne and travel out of our mouths and noses suspended in the "breath-air". The larger airborne droplets (LADs) and the smaller airborne droplets (SADs) have so little mass they do not move independent of the "breath-air" in which they are suspended. The *"Proceedings of a Workshop: Airborne Transmission of SARs-COV-2"* **Link** refer to Breath-air as *"respiratory plumes"* but the terms mean, and refer to, the same thing.

3.4 ***"Breath-air"*** description

Apart from when we deliberately blow out air, such as when we blow out the candles on our birthday cake, our breath-air air puffs gently out of our mouths as if we were little low-powered puffing steam engines. Our breath-air puffs when we speak, sing, laugh or cry.

The range of *"breath-air"* is very limited. the air moves fairly slowly and a face mask dramatically reduces the range.

See the excellent video (and still) in Figure 4 and the other videos on the BOHS Website and Tables 3a, 3b, 3c and Summary Table 4

Dramatically positive effect of wearing a face-mask

Small low-powered puffing 'steam engine'

Smaller low-powered wispy puffing 'Roman Candle'

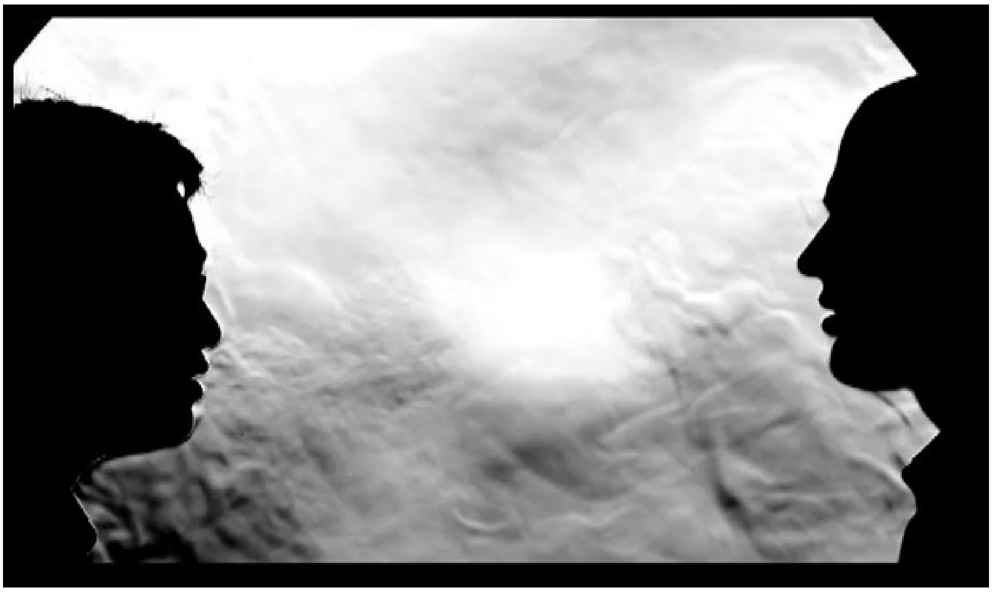


Figure 4 Talking breath-air range (photo) in quiet room air. ***Schlieren" still-photo shows talking "breath-air" shape and range*** Breath-air flow shape and range show up best in the (**video** **link**)

Note: It looks like the video was done indoors and in fairly still air. The layer of warm air rising off men's bodies is quite thick. The range of the breath-air each man creates as they talk looks and is limited (30 to 40 centimetres). In the video you can clearly see, their talking breath-air more-or-less puffs out of their mouths

3.5 *"Breath-air"* ranges summary including Tables

You can measure the range of your own *"breath-air"* with a simple DIY test which is described in Table 1.

In summary the range of the "breath-air" which can be felt on your wet-hand (see Table 1 for DIY test) and seen using vaping smoke is, unconstrained, normally less than 50 centimetres (0.5 metres).

When a facemask is worn the felt breath (by the DIY test) and the vaping smoke test is about 1 to 2 centimetres (0.01 – 0.002 metres). Although these ranges are approximate and take no account of how the breath-air flows once it's left your mouth. Almost certainly the breath-air range for quiet breathing when wearing a mask is greater than 1 to 2 centimetres, perhaps in the region of 5 to 10 centimetres.

The breath-air range for Blowing is the breath-air benchmark (Table 2). All other common human activities have breath-air ranges less than blowing. See Quiet breathing (Table 3a), talking (Table 3b) and singing (Table 3c). The breath-air ranges are summarised in Table 4. See the supporting explanatory videos on the BOHS Website **link**

Table 1
Do-it-yourself (DIY) *breath-air* range test

Do the test yourself today!

Human *"Breath-air"*	**Try the DIY test yourself**	**DIY *"breath-air"* test in four-simple-steps**
Puffs out of our mouths	Blow air at your hand and move your dampened hand away from your face to full stretch  Talk or sing at your dampened hand while and move your hand away from your face until you cannot feel your breath  Talk or sing at your dampened hand while wearing a facemask and move your hand away from your face until you cannot feel your breath 	1. Wet your hand and make it damp 2. Hold it in front of your face and blow at your hand. Move your hand away until your arm is at full stretch. You will feel the blown air at every distance 3. Do the same but this time speak or sing. You will find that you cannot feel your breath past about 50 centimetres (0.50 metres) 4. Repeat the simple DIY tests described in (3) wearing a facemask **DIY test conclusions:** a. *Breath-air"* is **real** and has a limited range of about 50 centimetres (0.5 metres) *b.* Facemasks **dramatically** reduce the range to a few centimetres at most[20]

[20] *"Proceedings of a Workshop: Airborne Transmission of SARs-COV-2"* Link refers to the same effect on *"respiratory plume"* travel

Table 2 Blowing – The breath-air range benchmark

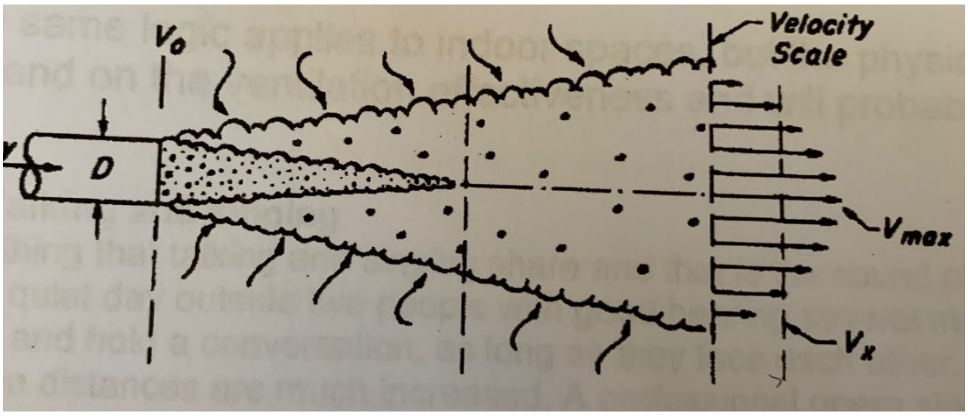
Classic air-jets are created by:

1. Continuous airflow
2. Which have **time** to entrain (draw-in) surrounding air (see Hemeon's diagram below the photo)
3. This increases the jet volume, momentum and range
4. Air-jets **take a little time to develop** but once they do, they can travel many metres
5. My blowing breath-range in still air was over 3 metre (not shown)

We only produce classic air-jets when we **blow air** (e.g. blowing out the candles on our birthday cake) or **when we sneeze or cough.** Quiet breathing, talking and singing do not produce classic air-jets with anything like the same range (See Tables 3a, 3b and 3c)

• The metre-rule on the wall provides some scale
• My blowing breath-air range in my unventilated study was over 3 metres (not shown)

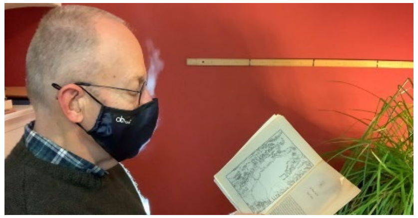
Hemeon's[21] beautifully simple diagram showing jet core-air, air-entrainment in the jet and jet-air expansion with travel from the jet-orifice (D – in the diagram)



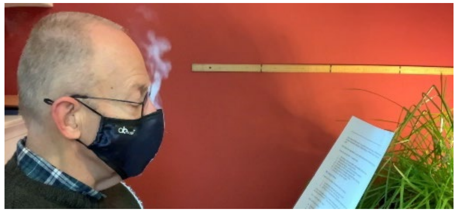
[21] Taken from WCL Hemeon's "Plant and Process Ventilation" 1955 See Review of Jeff Burton's re-print and edit here: [(11) (PDF) Hemeon's Plant and Process Ventilation, Third Edition (researchgate.net)]

Table 3a Quiet breathing breath-air ranges

How to interpret the images in this table: 1. See Table 1 for more on blowing breath-air benchmark 2. The smoke shows my *"breath-air"* range 3. Ignore the **density** of the smoke, it is the breath-air range that matters 4. Focus just on the range of my breath-air as shown by the smoke			**Blowing, the breath-air benchmark** (see Table 1 for details)	
Where?	**Quiet breathing**	**Where?**	**Quiet breathing**	**Quiet breathing conclusions: Breath-air range**
Indoors poor ventilation, without mask		**Indoors** poor ventilation, With a mask		**Without mask** *"breath-air"* range 50 – 75 centimetres (approx) **With mask** *"breath-air"* range 1.0 – 2.0 centimetres (approx)
Indoors good ventilation without mask		**Indoors,** good ventilation, With a mask		**Without mask** *"breath-air"* range 25 – 50 centimetres (approx) **With mask** *"breath-air"* range 1.0 – 2.0 centimetres (approx)
Outdoors good (variable) ventilation without mask		**Outdoors** good ventilation - With a mask		**Without mask** *"breath-air"* range 25 – 50 centimetres (approx) **With mask** *"breath-air"* range 1.0 – 2.0 centimetres (approx)

Table 3b Talking breath-range ranges				
How to interpret the images in this table: 1. See Table 1 for more on blowing breath-air benchmark 2. The smoke shows my *"breath-air"* range 3. Ignore the **density** of the smoke, it is the breath-air range that matters Focus just on the range of my breath-air as shown by the smoke			**Blowing, the breath-air benchmark** (see Table 1 for details)	
Where?	**Talking**	**Where?**	**Talking & mask**	**Talking conclusions: Breath-air range**
Indoors poor ventilation, without mask		**Indoors** poor ventilation, With a mask		**Without mask** *"breath-air"* range 25 - 50 centimetres (approx) **With mask** *"breath-air"* range 1.0 – 2.0 centimetres (approx)
Indoors good ventilation without mask		**Indoors,** good ventilation, With a mask		**Without mask** *"breath-air"* range 25 - 50 centimetres (approx) **With mask** *"breath-air"* range 1.0 – 2.0 centimetres (approx)
Outdoors good (variable) ventilation without mask		**Outdoors** good ventilation - With a mask		**Without mask** *"breath-air"* range 25 centimetres (approx) **With mask** *"breath-air"* range 1.0 – 2.0 centimetres (approx)

<table>
<tr><td colspan="5">Table 3c Singing breath-air ranges</td></tr>
<tr><td colspan="3">How to interpret the images in this table:
1. See Table 1 for more on blowing breath-air benchmark
2. The smoke shows my "breath-air" range
3. Ignore the density of the smoke, it is the breath-air range that matters
Focus just on the range of my breath-air as shown by the smoke</td><td colspan="2">Blowing, the breath-air benchmark (see Table 1 for details)
</td></tr>
<tr><td>Where?</td><td></td><td>Where?</td><td></td><td>Singing conclusions: Breath-air range</td></tr>
<tr><td>Indoors
poor
ventilation,
without
mask</td><td></td><td>Indoors
poor
ventilation,
With a
mask</td><td></td><td>Without mask "breath-air" range 25 - 50 centimetres (approx)

With mask "breath-air" range 1.0 – 2.0 centimetres (approx)</td></tr>
<tr><td>Indoors
good
ventilation
without
mask</td><td>Video lost – no still image available</td><td>Indoors,
good
ventilation,
With a
mask</td><td></td><td>Without mask Video lost – no still image available

With mask "breath-air" range 1.0 – 2.0 centimetres (approx)</td></tr>
</table>

Outdoors good (variable) ventilation without mask		**Outdoors** good ventilation - With a mask		**Without mask** *“breath-air”* range 25 centimetres (approx) **With mask** *“breath-air”* range 1.0 – 2.0 centimetres (approx)

Table 4 Breath-air ranges: summary and key comments

	Quiet breathing without mask	Quiet breathing with mask	Talking without mask	Singing without mask	Talking & singing with mask	Key comments
Indoors poor ventilation	25 – 75[22] centimetres	~5 – 10 centimetres	25 – 50 centimetres	~35 - ~70 centimetres	~5 – 10 centimetres	1. The breath-air ranges of **talking and singing are similar** at roughly 25 – 50 centimetres although singing can be 10 – 20 centimetres more becoming ~35 - ~70 centimetres **2.** The **maximum breath-air range**: quiet breathing indoors is 75 centimetres (see Footnote 12) 3. All **breath-air ranges fall when face-masks are worn** Using the DIY test and the vaping smoke test all breath-air ranges fall to about 1 to 2 centimetres (0.01 – 0.002 metres). **But Note:** These ranges are approximate and take no account of how the breath-air flows once it's left your mouth. Almost certainly the breath-air range when wearing a mask is greater than 1 to 2 centimetres, perhaps **in the region of 5 to 10 centimetres**. **4. Facemasks offer a layer of protection** mainly (but not only) because they **dramatically reduce** our *"breath-air"* range
Indoors good ventilation	25 – 50 centimetres	~5 – 10 centimetres	25 – 50 centimetres	~35 - ~70 centimetres	~5 – 10 centimetres	
Outdoors good (variable) ventilation	25 – 50 centimetres	~5 – 10 centimetres	~25[23] centimetres	~25 centimetres	~5 – 10 centimetres	

[22] Perhaps it's surprising that quiet-breathing breath-air range is greater than talking or singing. In fact, it illustrates the range impact of classic air-jets (see Table2 for some details). During quiet breathing my exhalation was slow and prolonged through my nostrils (see Table 3a). There was time for the two nostril-air-jets to be established. Talking and singing are far more staccato and there's little or no time for classic air-jets to form. Their breath-air ranges are therefore less.

[23] This is a bit lower than indoors good ventilation. Probably it was due to a gust of wind

3.6 Airborne droplet sizes – some thoughts

Droplets and particles of about 100 micrometres (aerodynamic) diameter and below are called *"inhalable"*. They can be breathed in through the nose and mouth.

The division of airborne droplets into larger and smaller is arbitrary but I still think it maybe a potentially useful division.

SARs-COV-2 viral infection can occur via the arrival of larger airborne droplets (LADs) or smaller airborne droplets (SADs) or small airborne particles (SAPs).

I believe (but I'm not sure) that the chances of a large dose of SARs-COV-2 virus being delivered to a small area of respiratory tract (RT) tissue is greater if the airborne droplet started off as a LAD. Why is this? Because of two reasons

1. LADs have a larger volume than SADs and **can carry** more SARs-COV-2 particles
2. LADs dry out slower than SADs so it's likely that their load of SARs-COV-2 viruses stay viable longer than SADs.

Airborne droplets (whether LADs or SADs) are all smaller than flying spit droplets and lose water much faster. All airborne droplets (whether LADs or SADs), suspended in the "breath-air", evaporate to dryness and become small airborne ('smoke') particles –(SAPs) within a few seconds.

The bigger[24] larger airborne droplets (LADs) might take less than, say, 4 seconds to dry out whereas the smaller airborne droplets (SADs) will definitely take less than a second to dry out. This time-to-dry-out is important. The bigger larger airborne droplets (LADs) move suspended in the "breath-air" and they may arrive at the face of someone nearby and be inhaled while still wet droplets (see Figure 1). In addition the flying spit droplets may land on a persons face including their eyes (if unprotected) (see Figure 1)

Where do smaller airborne droplets (SADs) land and why does their size matter and the fact that they are still wet droplets? These questions can be answered in five answers.

Answers:

1. The bigger larger airborne droplets (LADs) are large enough to carry many virus particles
2. They are still droplets when the land on the tissues of the nasal membranes and throat (Figure 1) so the load of viruses they carry are mainly still viable (capable of causing cell infection)
3. They deliver their load of viruses **in one go** to a very small patch of tissue
4. The tissue that the bigger larger inhalable droplets (LADs) land on is the nasal membranes and the back-of-the-throat (see Figure 1)

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[24] 100 micrometres (aerodynamic) diameter and above

5. Each one of the 100 micrometres in diameter larger airborne droplet (LAD) can carry well over the Minimum infectious Dose (MiD) of SARs-COV-2 viruses

All of which increases the chances that such large airborne droplets LADs) deliver well above the Minimum infectious Dose (MiD) of SARS-COV-2 virus whenever and wherever they land.

3.7 Airborne droplet/particle spread, dilution and infectivity

All LADs and SADs are carried suspended in "breath-air". They spread in the "breath-air" which flows and mixes with the surrounding air. The mixing dilutes the airborne droplet numbers. How rapidly (time) and how far (distance) can be divided into two questions:

i. *"How rapidly is the "breath-air" diluted* travel before mixing reduces the SARs-VOV-2 numbers below the Minimum infectious dose (MiD)*?"*
ii. *"How far does the "breath-air" travel before mixing with clean air* travel before mixing reduces the SARs-VOV-2 numbers below the Minimum infectious dose (MiD)*?"*

Breath-air dilution and travel

Given our size our breath-air volume is small for adults (between 600 millilitres in men and 500 millilitres in women[25]) and even smaller for children, about 250 millilitres. We really are, in effect, small steam engines puffing out our breath-air. Outdoors these small 'puffs' of breath-air are diluted in fresh air as are the airborne droplets/particles being carried in the 'puffs'.

Dramatically positive effect of wearing a face-mask

Small low-powered puffing 'steam engine'

Smaller low-powered wispy puffing 'Roman Candle'

Airborne viable virus concentration and both distance and time
Figure 4 (crudely hand-drawn) shows the relationship between airborne viable virus concentration and both distance and time and two Minimum infectious Doses (MiDs) representing original SARs-COV-2 and new variant SARs-COV-2.

The graph has three curves, one **blue** labelled "Curve a", another in **green** labelled "Curve b" and a third labelled "Curve c" in **purple**.

[25] Called the *"tidal volume"* – the amount of air we inhale and exhale at rest

The graph also shows two different Minimum infectious Doses (MiDs). It's been reported that the new variant SARs-COV-2 is more infectious. Figures of 70% have been quoted although it's current not clear where this figure has come from[26]. I have represented the new-variant SARs-COV-2 Minimum infectious Dose (Mid (ii)) in Figure 4 to show (crudely) what happens to distances and times if a lower MiD is assumed. I have assumed a 50% increase in infectivity.

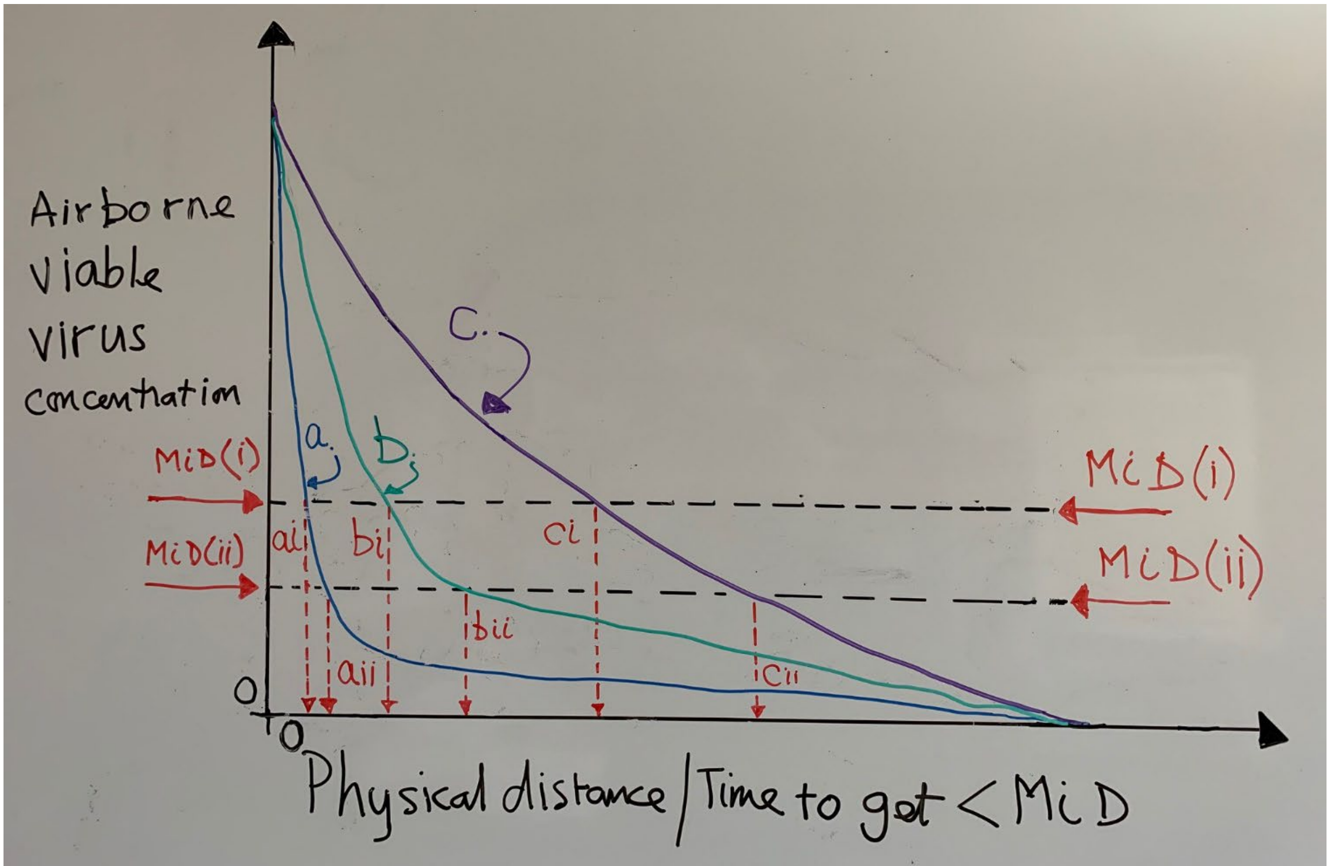

Figure 4 Airborne SARs-COV-2 viable virus concentration Minimum infectious Doses MiD (i) and MiD (ii) against Distance/Time to get below the MiDs (i and ii)

For clarity perhaps state under the graph MiD(i) = 'old' covid virus, MiD(ii) = new variant ?

"Curve a" falls steeply and then slowly approaches zero on the distance/time x-axis. **"Curve b"** falls less steeply but eventually approaches zero at the same point as "Curve a" on the distance/time x-axis. **"Curve c"** falls even slower and eventually approaches zero

"Curve a" shows what happens to airborne viable virus concentration outdoors. It shows how quickly the SARs-COV-2 virus concentration falls below the Minimum infectious Dose MiD (i)

[26] The new strain of SARs-COV-2 virus (*"Variant Under investigation"* VUI-2020/01 See BMJ reference 16th December 2020 **here** and Science Media Centre (SMC) **14th December 2020 here**

and MiD (ii). The physical distances or times (ai and aii) are close together for MiD (i) and MiD (ii).

Outdoors, differences in MiD have little effect on physical distances or times ((ai) compared to (aii)).

"Curve b" shows what happens in some of the better, most effectively ventilated, indoor spaces. It also shows how quickly the SARs-COV-2 virus concentration falls below the Minimum infectious Dose MiD (i) and MiD (ii). The physical distances or times (bi and bii) are fairly close together before breath-air is diluted below each MiD.

"Curve c" shows that in poorly ventilated spaces it takes longer for the SARs-COV-2 viable virus concentration to fall below either of the Minimum infectious Doses (MiDs). And greater physical distance have to be bigger than in a well ventilated space or outdoors (ci and cii).

But however effective or ineffective the ventilation is viable virus concentrations fall below either of the Minimum infectious Doses (MiD (i) and MiD (ii) eventually. The (admittedly crude) graphs also punch home the critical part that outdoor or well-ventilated spaces are much safer.

4.0 SAR-COV-2 virus exposure control measures

In workplaces there is a common hierarchy of exposure control measures[27]. A similar hierarchy can be used for SARs-COV-2 with some critical amendments. These amendments are needed because **we are the source(s)** of airborne contaminant – airborne droplets/particles containing SARs-COV-2 viruses.

In the industrial settings the sources of airborne contaminant are work processes. These may be fixed or mobile, close to workers or far away, strongly emitting or weaker but they are separate from the people involved.

With SARs-COV-2 virus, and other viruses and microbes, we are the sources of airborne contaminant. As sources we move around, there may be one of us or a number. We move through the environment outdoors and indoors always emitting airborne droplets and particles in our breath-air.

Exposure controls[28] start with changing the process to reduce emissions and/or reducing the number of sources. A similar approach works here by the use of face-masks to reduce our source emission rate.

Dramatically positive effect of wearing a face-mask

Small low-powered puffing 'steam engine'

Smaller low-powered wispy puffing 'Roman Candle'

Normally personal protective equipment (PPE) is towards the bottom of the exposure control options hierarchy but, in this case, the rigid application of the hierarchy can be put on one side. Because we are the source(s) of airborne contaminants and face masks reduce our 'source strength' a lot.

See Tables 3a, 3b and 3c and the summary table 4 on breath-air ranges and the impact of face masks. Face masks, it turns out, are critical to effective source control.

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27 Starting with changing the processes to reduce emissions and moving onto controls that are applied to processes and workplaces, such as ventilation (local and general) and behavioural controls which may include the use of personal protective equipment (PPE).

28 Andy Gillies (see Acknowledgements) brought my attention to **Professor JVT** and his useful acronym CCC+D&V. The professor's idea of risk factors to consider in trying to reduce infection he sums up as ***"three C's plus D and V"*** i.e. (avoid) Close contact with people in Cramped indoor environments, Crowded with lots of people, (and minimise) Duration of exposure and places with high noise Volume (meaning people have to raise their voices or shout to be heard

Figure 5 taken from the recent US Workshop sums up neatly the relevant SARs-COV-2 exposure control measures

Figure 5 shows the four basic SARs-COV-2 virus exposure control measures

1. Physical distancing
2. Ventilation
3. Face-mask wearing
4. The need for skin hygiene

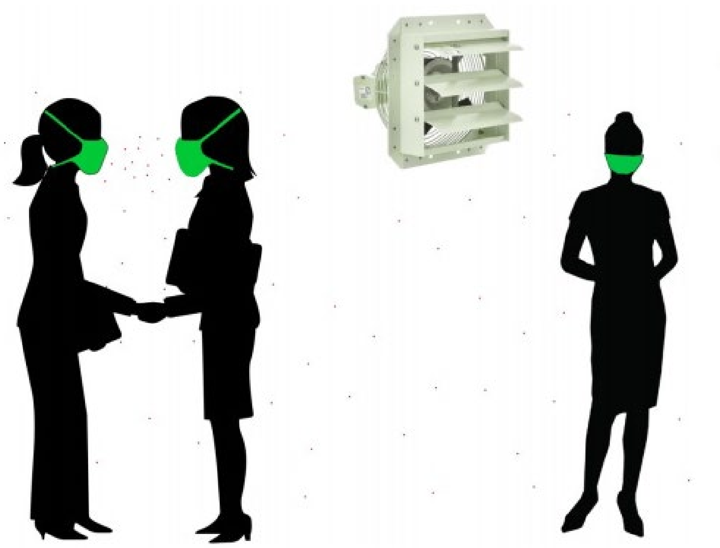

Figure 5 taken from "Proceedings of a Workshop: Airborne Transmission of SARs-COV-2" ***Link.***

4.1 Face-masks – why they are effective

Face-masks respirators and maybe face-shields work in **two** ways.

1. Well designed and reasonably well fitted facemasks have far more protective effect than at first was realised at the start of the COVID-19 pandemic**. Face-masks do filter out larger airborne droplets (LADs)** quite well. And they stop the flying spit droplets when we speak or sing.
2. But their **main protective effect** is due to the way **they dramatically reduce the range of our breath-air** as shown in Tables 3a, 3b and 3c and summarised in Table 4. See also the videos of me vaping with and without a face-mask

4.2 Videos of practical virus exposure control measures in action

Rather than just go through the hierarchy of exposure control measures by rote I've used a selfie-stick to show a journey up Kings Heath High Street in South Birmingham and shopping visits to Boots and Sainsbury's**.** The Background Notes for the videos are in Appendix 1. The video itself will appear on the BOHS Website (**BOHS**).

1.3 Respirators[29] give more protection than face masks

a. Well-fitting respirators, designed and manufactured to recognised standards, will provide better protection than facemasks

b. They could be used by vulnerable people instead of face-masks and should be used by people exposed to huge numbers of smaller airborne droplets (SADs), for instance, health care workers in Intensive Care Units (ITUs) [30].

4.4 Face shields

Face shields stop flying spit droplets (see Figure 1). They are worn by themselves as a substitute for a face mask. They will not restrict the range of our breath-air as much as a face mask but they will restrict it. This will be good-enough outdoors and maybe good-enough in well ventilated rooms/shops indoors. They are probably more comfortable to wear over a long time than face masks. Whether they are the equivalent of face masks in poorly ventilated spaces is doubtful.

4.5 Physical distancing between people

Tables 3a, 3b and 3c show the ranges of breath-air under different conditions when wearing and not wearing face masks. And there's a Summary breath-air distances Table 4. **You can use the distances in these tables.**

The physical distances needed vary:

1. Outside in fresh air - 1.0 to 1.5 metres
2. Inside large well-ventilated spaces - 1.5 to 2.0 metres
3. Inside small poor ventilated spaces, greater than 2.0 metres (and/or leave the space)

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[29] To be called a "respirator" a device has to meet an agreed test standard, These usually rank respirators into 'protection factor' categories which indicate whether the device is likely to reduce exposure by, for instance, 5-times or 10-times or 40-times. Respirator standards vary across the world, but they are comparable. The respirator test standard tests use clouds of small airborne particles (SAPs). Protection against larger airborne droplets (LADS) by respirators is likely to be greater than the standard 'protection factor' categories suggest.

[30] Tight-fitting respirators are difficult to wear for a long time. Where high protection factors are needed for length periods people could be supplied with and wear powered air purifying respirators (PAPRs)

4.6 Physical barriers

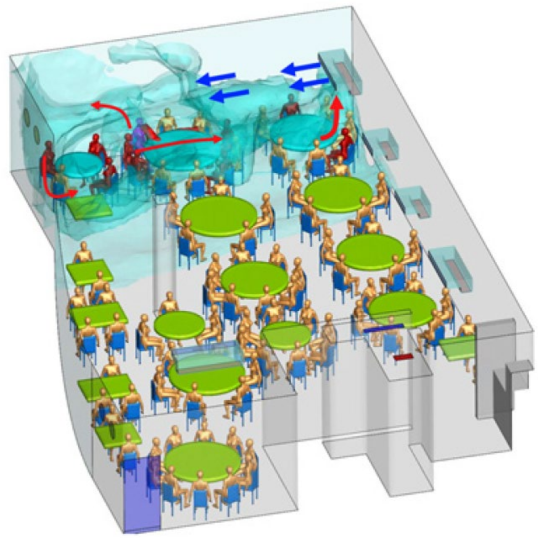
Barriers such as the plastic transparent ones now found in shops reduce the range of breath-air 'smoke' not as much as visors and certainly not as much as face masks but probably reasonably well.

4.7 Ventilation

Poor dilution and dispersion ventilation and COVID-19 *"Super-spreading"* events

All of the *"super-spreading"* events have happened indoors in places with poor dilution and dispersion of the room air or where the ventilation simply recirculates stagnant air in a restricted area of a room (see *"Proceedings of a Workshop: Airborne Transmission of SARs-COV-2"* **Link**)**.** People's breath-air 'smoke' wasn't diluted enough and airborne viable SARs-COV-2 virus concentrations rose to and exceeded the Minimum infectious Dose (MiD) and some people got COVID-19.

See **"Curve c"** in Figure 4 and Figure on right taken from Workshop Proceedings.



Dramatically positive effect of wearing a face-mask

Small low-powered puffing 'steam engine' | Smaller low-powered wispy puffing 'Roman Candle'

The "super-spreading" events indicate that it's vital that people's breath-air 'smoke' is well diluted and dispersed. This is much more easily achieved if everyone is wearing a face mask or face shield.

Outdoors

The most effective dilution and dispersal of breath-air occurs outdoors. Outside air is in constant large-scale movement. Ideal for dilution and dispersal of breath-air 'smoke'. Even a slight wind will rapidly dilute and disperse our breath-air 'smoke' (See **"Curve a"** in Figure 4)

Large well-ventilated spaces

Next in terms of effective dilution and dispersal, comes large well-ventilated spaces (e.g. supermarkets).

The volume of large rooms automatically increases breath-air ‘smoke’ dilution and dispersal, compared with small rooms.

The air in large rooms, such as supermarkets, is kept in constant turbulent motion by air conditioning fans and all the fans in open-fronted food chillers and freezers.

Ventilation effectiveness in such well-ventilated rooms probably looks like **“Curve b”** in Figure 4.

Effective ventilation is key and is coupled with other exposure control measures including facemasks, barriers between check-outs (in supermarkets and similar places) and physical distancing. With all these exposure control measures in place the chances that breathing-air ‘smoke’ from a COVID-19 infected person reaches and stays at the SARs-COV-2 Minimum infectious Dose (MiD) is very unlikely. The risk is more than being outdoors, but it is still low.

4.8 Improving ventilation in rooms[31]

Using a Concept Engineering machine **link**, I filled our bathroom full of smoke to show the effectiveness of:

1. Poor ventilation (Doors and window closed)
2. Some ventilation (Window open)
3. Better ventilation (Door and window open creating a through draft)

I videoed the smoky air and did time-lapse videos with my iPhone over five minutes for each test. All the videos can be seen on the BOHS Website **link**

Table 5 shows stills taken from the videos which summarise the effectiveness of the ventilation improvements to our bathroom.

1. With poor ventilation there is hardly any discernible dilution and dispersal of the smoke.

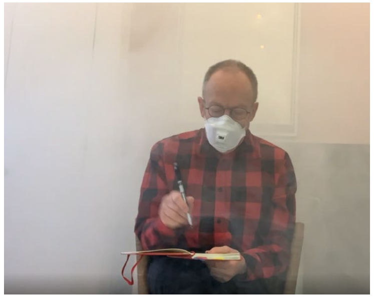
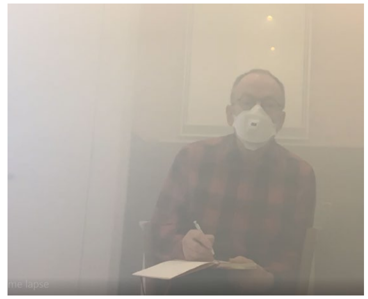
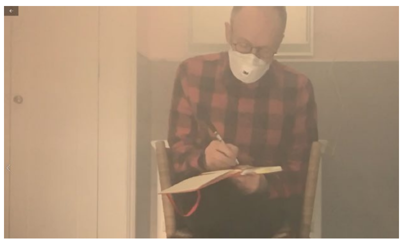
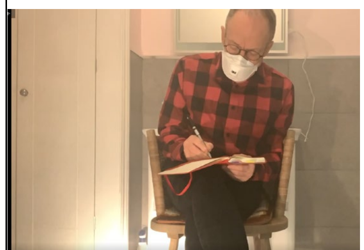
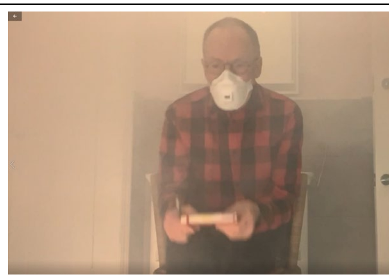
2. With some ventilation (window open) the smoke is diluted and dispersed quite well but some is still present at the end of the five minutes.

3. With better (through-draft) ventilation, after five minutes, the smoke has been completely diluted and dispersed

[31] Smoke is good but exact measurement is better. The Health and Safety Executive (HSE) used to publish an MDHS (Methods for Determining Hazardous Substances) on using trace gases to empirically measure room ventilation rates. It doesn’t seem to be in-print which is a pity as it was useful guidance which I’ve used myself in the dim-and-distant past.

At home or in, for instance, small shops and offices simply opening the windows and/or doors will dilute our breath-air ‘smoke’. Creating a through-draft is even more effective. And ‘stirring the air with a fan or fans improves mixing and dilution. If the ‘stirring’ fans filter the air too, so much the better.

Table 5

Ventilation	Start	~1½ minutes	~5 minutes	Comments
1. Poor ventilation (Doors and window closed)				Hardly any discernible change in smoke density over five minutes
2. Some ventilation (Window open)				Smoke density quite bit less at the end of five minutes
3. Better ventilation (Door and window open creating a through-draft)				Smoke almost disappeared , apart from near the bathroom ceiling where the through flow of outside air doesn't mix well with the room air

Simply opening the window(s) and/or leaving the door ajar will improve ventilation and will dilute and disperse our breath-air smoke. Even more effective is to create a through draught of air. Additional 'stirring' of the air in a room with a fan or fans will increase air mixing and dilution and dispersal of any airborne SARs-COV-2 viruses.

This is our local One-Stop shop. All customers wear face masks. The doors regularly open as customers come and go. Each time this happens some fresh air enters the shop.

The open-front fridge food chiller units run almost down one side of the shop. The fans in these units 'stir' the shop air creating constant turbulent mixing of the air. These simple (inadvertent) ventilation arrangements, plus the face masks and physical distancing, make it very unlikely that the SARS-COV-2 Minimum infectious Dose (MiD) will be exceeded and COVID-19 infection will occur.

I would make only two additional exposure control recommendations to One Stop staff:

a. Open a door or window at the back of the shop to create a through-draught.
b. Turn on the ceiling air conditioning unit fan to increase 'stirring' of the air

Principles of SARs-COV-2 control

The same principles apply to any room at home or in, for instance, an office:

1. Open window(s) and/or door(s) to create a through-draught

2. ‘Stir’ the air in the space with a fan or fans
3. Wear a face mask or face visor
4. Keep to the physical distancing rules
5. Limit the number of people in the space
6. Put up physical (transparent) barriers to limit breath-air spread
7. Provide facilities for effective surface and skin hygiene

4.9 Surface and skin good hygienic behaviour
Inhalation of airborne droplets/particles or direct impact of flying-spit droplets on the eyes (Figure 1) are **the main ways** SARs-COV-2 virus spreads.

Flying spit droplets can also contaminate surfaces and skin. It’s then possible for someone to contaminate their hand and transfer SARs-COV-2 virus to their eyes or mouth. But this route/pathway is far less likely than inhalation of airborne droplets/particles. Nevertheless, good surface and skin hygiene are part of the layered control measures.

When entering and leaving a shop use the skin hygiene facilities or your own skin sanitiser. Wash your hands-on returning home or going to the office.

As for picking up a lot of SARs-COV-2 viral particles from letters and parcels etcetera this is an even more unlikely route. Nevertheless, it may be worth washing your hands after opening letters and parcels especially if this reduces your anxiety.

4.10 Meeting other people safely outdoors and in other well-ventilated spaces

Table 6 covers common things we all do and experience, how to do them safely and why it is safe to do so.

Table 6 Meeting, and passing-by other people safely outside

Meeting circum-stances	**Advice/ Options**	**Why this approach is relatively low risk**
Passing someone when you are both silent Walking towards someone walking towards you	Smile, walk past the other person at, say, 1.0 – 1.5 metres separation.	If neither of you is talking, your breath-range is up to or less than 50 centimetres. Although you are both emitting ultrafine droplets/particles, they don’t settle to any extent and are unlikely to pose infection risk (see main text sub-section 3.1 for a bit of detail) If you’re both wearing face masks, it’s highly unlikely you pose a risk to each other Smile, nod, greet and pass on your way
Passing someone (adult) who is talking Walking	Smile, say *“Hi!”* or similar, walk past the other	Saying *“Hi!”* or *“Good morning”* will produce a puff of breath-air which is rapidly diluted. The chances of you or the other person receiving a the Minimum infectious Dose (MiD) of SARs-COV-2 from such a brief encounter is unlikely

Table 6 **Meeting, and passing-by other people safely outside**		
Meeting circum-stances	**Advice/ Options**	**Why this approach is relatively low risk**
towards an adult walking towards you who is talking	person at, say, 1.0 – 1.5 metres separation. .	
Talking to another adult Meeting a friend and talking to them	Keep at least 1.5 – 2.0 metres apart	Air puffs out of our mouths when we speak as if we're small low-powered small puffing steam engines (See Table 1 for the DIY *"Breath-air"* test and Table 3b for results of talking breath-air range tests) Our voices are very directional and carry a long way. You'll still be able to hear your friend at 1, 2 or more metres so step back a bit if you want. The risk of receiving a Minimum infectious Dose (MiD) of SARs-COV-2 talking outside at least 1.5 – 2.0 metres physical distancing is very unlikely
Passing a small child who is talking Walking towards children (talking intently) who are walking towards you	Smile and try to pass the children with, perhaps, 1.0 metres separation.	Children talking continuously will produce flying spit droplets that fall out of the air below adult head-height. A child's *"breath-air"* volume is about half of an adults[32] and their breath-air range will be smaller too. If we're small low-powered puffing steam-engines then their puffing is even smaller. Their breath-air is diluted rapidly
Singing to another person or in a choir outside	Keep at least 2.0 metres apart	Air puffs out of our mouths when we sing. See Table 1 for the DIY *"Breath-air"* test and Table 3c for singing breath-air range tests There are singing-face-mask designs which stick out from the face. In a choir they should probably be worn if the choir is singing in large(ish) numbers. Just to be on the safe side. 
Someone runs towards and past you	Keep at least 1.0 – 1.5 metres apart	Air flows out of runner's mouth with more momentum than quiet breathing. His/her breath contains ultrafine droplets/particles (see sub-section 3.1). These don't settle to any extent and are unlikely to pose an infection risk

[32] About 250 millilitres compared with about 500 millilitres

5.0 Final comments

5.1 Droplets or breath-air?

The exposure control measures needed to minimise spread of SARs-COV-2 virus apply whether or not larger airborne droplets (LADs) matter more than smaller airborne droplets (SADs). **It's the range of our breath-air and its dilution which is utterly critical.**

When I started out trying to write the Notes I thought, like many, that Larger Airborne Droplets (LADs) were more important in spreading the SARs-COV-2 virus than the smaller airborne droplets (SADs). When we are very close (around 25 centimetres) this is probably true – See Figures 1 and 1a.

At distances greater than 25 centimetres the details of exactly which airborne droplets or particles carry how many SARs-COV-2 viruses don't matter as much as how our breath-air is emitted and is diluted. What's **really important is the range of our puffing "breath-air"** and **how it is diluted with fresh air** after it flows out of our mouth and/or nose.

Unless we're blowing out the candles on our birthday cake we don't produce classic air-jets (See Table 2). Our breath-air comes out in staccato puffs when we talk or sing. When we do our breath-air range is about 50 centimetres when talking. And further for singing at about 70 centimetres.

Dramatically positive effect of wearing a face-mask

Small low-powered puffing 'steam engine'

Smaller low-powered wispy puffing 'Roman Candle'

This is reduced to 5 to 10 centimetres if we wear a face mask (or face-shield) when talking or singing.

Keeping a reasonable physical distance and wearing facemasks in shops, coupled with reasonable ventilation reduces the risk very significantly.

Defining "reasonable ventilation" is difficult. Outside air is the benchmark. Inside ventilation will dilute and disperse breath-air 'smoke' less effectively but in many cases is probably good enough.

Any airborne droplets carrying SARs-COV-2 viruses are diluted to the point where they cannot deliver a Minimum infectious Dose (MiD) – Figure 4 and commentary.

1. Our puffing staccato breath air is of very limited range so physical distancing works
2. A simple face mask reduces our breath-air range to almost nothing
3. Reasonable general ventilation dilutes and disperses SARs-COV-2 emitted in our breath-air

5.2 Sciences and the SARs-COV-2 & COVID-19 jigsaw puzzle

The jigsaw puzzle metaphor of the relevant sciences working on ‘their-bit’ of the puzzle (see sub-section 1.5) that is SARs-COV-2 & COVID 19 works quite well. Eventually more hard scientific work will clearly show the whole picture, in crisp detail, on the lid.

The jigsaw puzzle metaphor also reminds us that to get the full picture of what is going on you need a mix of views, a mix of sciences. A point that was very well made in the US National Academies October Workshop **Link**

> *“The discussants noted that making progress on remaining unknowns will require interdisciplinary research…”* (and some areas covered by different sciences are listed)

And this raises another interesting thought - One person or science cannot ‘speak for science’ because the problem demands the input of the relevant sciences (plural). It needs the noisy voices of all the relevant sciences working together and thrashing out a credible true jigsaw puzzle picture.

The applied science of occupational hygiene does illuminate part of the SARs-COV-2 & COVID 19 puzzle and helps particularly with practical exposure control measures.

5.3 Sciences and the next pandemic
There will be another pandemic; that’s for sure. When it happens and governments and others dust-off the old 2020 COVID-19 pandemic plans the key lesson, the exhortation to put in big shiny letters on the front cover as the US National Academy of Sciences said,

> “(this), *will require interdisciplinary research”*

The governmental job next time is to ensure that the right mix of sciences work noisily together playing to their different strengths, so that the picture on the pandemic jigsaw-puzzle box becomes clear-enough so that practical exposure control measures can be developed and applied as quickly as possible.

5.4 Occupational hygiene and other research needed
In Appendix 3 I’ve had a stab at some of the multidisciplinary scientific research that’s probably needed to prepare us for the next pandemic. Meanwhile I hope you find these *"Basic Notes"* based on occupational hygiene insights make sense and are useful to you.

Best wishes and good luck in the pandemic. Roll-on the huge vaccination programme!

Mark Piney
5th January 2021

PS Please look out for the simple messages which will be generated by British Occupational Hygiene Society (BOHS) staff and the videos that illustrate this guidance (**BOHS**).

6.0 Acknowledgements

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- Last but not least Emma and Lea Lucor would drew the lovely (almost cuddly) SARs-COV-2 viruses and Figure 1.

7.0 Dedication to Alan McArthur

These Basic Notes are dedicated to the memory of Alan McArthur[33]

7th March 1971 – 28th February 2018
(3M Technical Supervisor Respiratory Protective Equipment (RPE))

Please donate to **this fund,** set up by Alan's colleagues at 3M, in support of Mind, the mental health charity

[33] Alan took his own life on 28th February 2018. He was 47 years old. I knew him quite well and it is a great sadness that I didn't know that he suffered from deep depressive moods. Modern psychotherapies, like Compassion Focused Therapy (CFT) do work.

Appendix 1 Meeting with others safely (social distancing) Gov't rules

***Guidance Coronavirus (COVID-19): Meeting with others safely (social distancing)* 7th January 2021 (Extract)**

"*Hands. Face. Space.*

Approximately 1 in 3 people who have coronavirus have no symptoms and could be spreading it without realising it.

It is critical that everybody observes the following key behaviours:

- *HANDS - Wash your hands regularly and for 20 seconds.*
- *FACE - Wear a face covering in indoor settings where social distancing may be difficult, and where you will come into contact with people you do not normally meet.*
- *SPACE - Stay 2 metres apart from people you do not live with where possible, or 1 metre with extra precautions in place (such as wearing face coverings or increasing ventilation indoors).*

It is important to meet people you do not live with outdoors where possible. If you meet people you do not live with indoors, such as someone working in your home, you should make sure you let as much fresh air in as you can without getting uncomfortably cold (for example by opening windows)."

Coronavirus (COVID-19): Meeting with others safely (social distancing) - GOV.UK (www.gov.uk)

Appendix 2 Background Video Notes

Walk up Kings Heath High Street and shopping at Boots and Sainsbury's on 11th December 2020

I'm walking down Kings Heath High Street in South Birmingham.

The weather is cloudy, there's a bit of drizzle, the wind is south-southwest (SSW) with a speed of between 7 and 15 mph (mph).

I am wearing my *"A– B mask"* **link** which means my breath–air reaches between 2 and 3 centimetres out from my face. My breath-air (if you could see it) would make me look like a low-powered Roman-Candle firework, producing wispy puffs of air from my masked-face.

Even without my face-mask, I leave a trail of breath–air puffs which are rapidly diluted in the wind. I'm not talking, I'm simply breathing. The only airborne droplets/particles I am releasing are ultrafine which, if I had COVID-19, would carry almost no infection risk to anyone else (see Basic Notes text for further explanation).

I pass others quickly, some wearing face–masks, others not so. What risk do they pose to me or I to them? The breath–air range of those talking, with no face masks, is approximately 25 cm. The puffs of breath–air as talk are rapidly diluted in the outside air. As I am wearing a face mask the risks are, in practice, negligible.

Shopping in Sainsbury's and Boots 11th December 2020

I'm buying some raspberries in Sainsbury's and various items in Boots while wearing my *"A– B mask"* **link** and most people in the shop are wearing masks too. Our breath–air reaches between 2cm and 3 cm out from our faces. Our breath-air (if you could see it) would make us look like a low-powered Roman-Candle firework, producing wispy puffs of air from our masked-faces (see Basic Notes text for further explanation).

Inside the shops we're not (in the main) talking, we're simply breathing. The only airborne droplets/particles we are releasing are ultrafine which do not settle and are unlikely, if someone had COVID-19, to cause infection.

The facemasks mean our breath-air is emitted in wispy puffs. The ventilation and air movement generated by, for instance, chilled, open-fronted fridge units means the air in the shop is in constant turbulent motion. Depending on the design of the air-conditioning some of the air may be filtered. But this isn't the important point which is that the constant air motion rapidly dilutes and disperses our wispy breath air. It doesn't matter if the ventilation in shops filters the air, as long as it creates air movement that is enough to disperse and dilute the wispy breath-air we emit.

Exposure control layers at Sainsburys, Boots and many other shops include:

The random constant air movement. The facemask wearing. The barriers between the check-outs. The physical distancing in queues. The freely available skin and surface hygiene facilities. All mean that when visiting modern shops, the risk of receiving more than the Minimum infectious Dose (MiD) of SARs-COV-2 is very unlikely. Not as low as being outside where the risk is highly unlikely but good enough

Appendix 3 Occupational hygiene (OH) and other scientific research - a few thoughts

Occupational hygiene (OH) and other scientific research - a few thoughts

Research question(s)	Description	Discussion points	Sciences comments
How much does surface and skin contamination play a part in SARs-COV-2 (and other virus) transmission?	It's pretty obvious with SARs-COV-2 that the **primary transmission pathway** is through the air. It's not clear how much surface-skin transfer plays in transmission. It would be useful to roughly quantify this pathway.	SARs-like cold viruses can be transmitted from nose to skin to nose/mouth especially in young children (who can be very snotty). SARs-COV-2 will be transmitted this way but, probably, not a lot. Finding out how much surface-skin contributes matters in terms of public fear and economic costs.	OH research into surface and skin contamination will be relevant but also virology in examining virus viability on surfaces and skin and the most cost-effective ways of cleaning surfaces and skin. Pathway quantification will be difficult but is worth doing.
What difference do different physical distances make to infection risk?	I've assumed that larger airborne droplets (LADs) can carry more viable virus than smaller airborne droplets (SADs) because they dry out more slowly. And the infection risk is greatest in the "near field" close to someone infected with COVID 19.	Current airborne virus sampling methods damage viruses collected. Although their RNA is detected, it's not clear what % of viruses are viable and able to infect. Gentler methods of sampling are needed.	Airborne droplet/particle sampling focussing on inhalable, thoracic and respirable fractions will be relevant (OH and aerosol physics). But how to measure the viability of viruses is the province of virology.
Cold and hot environments and climates appear to affect SARs-COV-2 transmissibility. What are the mechanisms(s) which cause these differences?	Some UK outbreaks have been associated with food/meat-packing warehouses which are kept cold. It appears that some countries e.g. Rwanda have had far less COVID-19 death[34]. Increases or decreases in transmission will be due to multiple factors. It's likely that temperature and UV light intensity will be important	The factors increasing or decreasing SARs-COV-2 transmissibility will be multiple. Colder environments are likely to increase virus viability and higher levels of UV light are likely to decrease it. And perhaps warmer environments mean that doors and windows are left open automatically increasing ventilation	Sciences involved could include: Ergonomic human factors, occupational hygiene, physics, virology, epidemiology

[34] Recent broadcast of *"More or Less"* on BBC World Service showed that Rwanda had 300 times less COVID-19 deaths compared with Belgium which has a comparable sized population to Rwanda

Occupational hygiene (OH) and other scientific research - a few thoughts

Research question(s)	**Description**	**Discussion points**	**Sciences comments**
		effectiveness. The demographics of different countries has an impact on mortality.	
Quantification of ventilation effectiveness	The term *"effective ventilation"* needs to be defined experimentally using tracer gas empirical work[35] and CFD modelling used together. Smoke testing is all very well but it is not quantitative.	As long as airborne droplets/particles carrying SARs-COV-2 viral particles are diluted and dispersed effectively, COVID-19 infection is prevented. But exactly what poor, good and very good dilution and dispersion ventilation means needs to be defined.	Sciences involved could include ventilation engineering, and occupational hygiene.
Quantification of face mask effectiveness	EN standards are in development but world-wide standards are needed.	The main impact of face masks is on breath-air range and not simply filtration. Quantitative ways of measuring breath-air range are needed.	Physics (aerosol science) and OH and probably ergonomics on wearability and comfort of face masks.
Respirators are designed for industrial use and, usually, intermittent exposure when, and for some time after, a process has stopped running. In health-care environments respirators maybe worn for hours on end. These conditions demand more of the wearers and the RPE.	Some tight-fitting RPE may be fine but this needs properly checking. Where people have to wear RPE for long periods it should be a PAPR (Powered Air Purifying Respirators).	The most comfortable tight-fitting RPE is probably FFP devices with exhalation valves. Industrial PAPR can noisy and some are heavy. There's design work to do to make them quieter and improve PAPRs so that wearers can communicate. They probably need to be lighter than current 'industrial' designs.	Sciences involved: PPE engineering, ergonomics, social psychology, occupational hygiene (others?).
Which lung tissues get infected	Figure 1 suggests that flying	Deep lung direct infection by	Sciences involved:

[35] The HSE Method for Determining Hazardous Substances (MDHS) explaining how to measure ventilation effectiveness seems to be out-of-print. It would be well worth updating and republishing it

Occupational hygiene (OH) and other scientific research - a few thoughts

Research question(s)	**Description**	**Discussion points**	**Sciences comments**
by SARs-COV-2 virus – upper respiratory tract or upper and lower respiratory tract.	spit droplets and the larger inhalable large airborne droplets (LADs) lead to infection of the upper respiratory tract. In circumstances where smaller airborne droplets/particle (SADs and SAPs) are large in number (e.g in poorly ventilated spaces or where Aerosol Generating Processes (AGPs) are used in a medical setting, it's possible that the tissue of the lower respiratory tract is infected too or in preference.	SARs-COV-2 is likely to be more serious than infection of the upper respiratory tract. How infection difference airborne droplet/particle size fractions are likely to be and where they preferentially land maybe important determinants of the severity of COVID-19.	Aerosol physics (OH), lung physiology, virology and immunology.
How and why does the SARs-COV-2 Minimum infectious Dose (MiD) vary with age and underlying health conditions and SARs variants.	It's likely that the SARs-CoV-2 MiD is different for different groups and different variants of the virus. It would be useful to better understand the mechanisms underlying these differences to better bracket likely Minimum infectious Doses (MiDs).	Why Minimum infectious Doses (MiDs) vary could be due to less effect respiratory tract clearance, or a weakening of the immune system or other factors.	Sciences involved could include aerosol physics, lung physiology, immunology, virology, genomics (and others?).