Known Unknowns:
Known Knowns and COVID mitigation

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Abstract

This article will review the evolution of our response to the COVID crisis. In particular the tools and strategies that are being put forward to assist in making spaces safe for habitation. In many cases there are shortcomings that are well documented, however we overlook these 'Known Knowns' in order to make ourselves feel better about doing 'something'. In some of these cases a simple tweak might make a major improvement, in other cases we are just throwing good money after bad. In extreme cases we are being outright fraudulent and hoping some money can be made before somebody calls it out. In all cases, the work has been done and the knowledge is there that can allow us to make better choices that will make a difference.

Introduction

It's always interesting to see terminology that you use in your (somewhat esoteric) day job start popping up in your social media feed. The recent discussion on the role that aerosols contribute to COVID-19 infection compared to droplets intersects with many concepts we employ in the design of cleanrooms.

Put simply, droplets are generally particles larger than 5 micron that when generated tend to settle onto surfaces and can only be removed by cleaning. Aerosols are generally less than 5 microns, tend to be easily entrained in the airflow and are removed by well-designed air conditioning systems.

Usually in cleanrooms we think of particles as solid objects. Liquid droplets and aerosols are a bit different because they change size over time due to evaporation. Therefore, a largish droplet falling to the floor can become an aerosol (dried residue) before it gets there, becoming a droplet nuclei (we will call them this to differentiate them from regular aerosols). However, if still liquid, once it lands it is unlikely to be re-entrained by local air movement. The proportion of droplets that hit the floor or remain in the air as droplet nuclei is determined largely by the humidity. The higher the humidity, the fewer the droplets that evaporate down to droplet nuclei and the higher the proportion of droplets that hit the floor. The lower the humidity, the more and the larger are the droplets that become droplet nuclei which can re-entrain in the airflow.

The original work on liquid droplet behaviour dates from 1934 through work by the US sanitary engineer William F. Wells.[1] The Wells curve and the subsequent work with Richard L. Riley to create the Wells-Riley Model, was used to demonstrate airborne transmission of Tuberculosis. Over time the Wells curve has been improved upon and used in other research, such as that on the transmission of measles.

In the light of this work, it is puzzling why it was not the go-to-model at the outbreak of COVID. Indeed, it was not into late 2020 after some intense lobbying of the WHO by 239 experts, led by Lidia Morawska and Donald Milton through the paper *It Is Time to Address Airborne Transmission of Coronavirus Disease*[2] before airborne transmission was properly considered and ultimately accepted.

This is a true case of a 'known known', where previous work is forgotten or dismissed, however such 'known knowns' are to be ignored at their peril. The myriad of equipment that are turning up in our schools, workplaces and social spaces to keep us safe are there to do an important job. Mostly they have a sound scientific basis, but some seem to have missed a fundamental 'known known' which makes them much less effective than we would like them to be.

What are we trying to solve?

Mitigating airborne transmission of COVID-19 is an important and immediate need as Europe and the US potentially enters its "fourth wave". The challenge is to find the mitigation that is truly effective, as many mitigations really only nibble around the edges. A mitigation that addresses a minor risk can end up distracting from the real problem. Similarly, we need to look at all aspects of the physics and engineering to assess if the mitigation is truly effective. The principles of cleanroom design are uniquely positioned to contribute to this body of knowledge.

Specific risks for specialist areas, such as COVID hospital wards aside, the key challenge for infection mitigation is against close contact in spaces where numerous people can be found in an enclosed environment. This includes offices, schools, public transport and restaurants.

Taking the lead from cleanroom design, any contamination generated ideally needs to be removed from the critical zone quickly and effectively. While unidirectional airflow is unlikely to be viable in a public setting, the concept of net downward flow is attractive; liquid droplets and aerosols that are forced to a surface are unlikely to re-suspend.

This is just one concept. There are a range of other potential mitigations that can be employed; let's look at those we know to see how effective they really can be.

Air dilution

Air dilution is the mainstay of non-unidirectional cleanrooms, however there are certain caveats. One is that the dilution needs to be in proportion to the contamination present. Dictating a specific air change rate may be effective in certain settings, but definitely not all. Air replacement through open windows and single pass air provide an additional level of dilution, but it is not possible to do this throughout the year or maintain a level of climate control without equipment modification.

The amount of viable SARS-CoV-2 virus that can make it through an air conditioning system would be difficult to determine accurately, however even with a rudimentary filter system, low air change rates and high level return air points, you would expect that dilution would be pretty significant. Whether that dilution is a sufficient mitigation will depend on many things; for example, with a highly vaccinated population a small concentration of virus is not significant whereas with a largely un-vaccinated population, a small concentration of virus is potentially significant.

Air movement

Air movement is an essential requirement to do the work that gravity cannot, however non-targeted movement can just take contamination from one critical area to another. For example, a pedestal fan blowing past one person and onto another just provides an effective contamination conduit.

A local school guideline[3] I have reviewed mentions the use of ceiling fans.

If used, ceiling fans can be operated on the winter setting (where air is drawn upwards) and at the lowest speed.

While ceiling fans are not used in cleanrooms, we go back to the principal that we would want a downdraft to push particles down to where they will hopefully adhere to a surface. Drawing air upwards is a convenient way to redistribute particles. Of course there will be updraft at some point regardless of the rotation of the fan, so potentially there may be the same problem at the transition zone between downdraft and updraft.

What a ceiling fan will do however is better distribute the air around the room, which will disperse high concentrations around a room. Again, potentially of benefit for highly vaccinated populations only.

Air purifiers

The use of air purifiers has been promoted from the early days of the pandemic. Their effectiveness in cleaning the air is well documented and typically involve the use of HEPA filters. However, their effectiveness will only be as good as their air distribution. They may clean air within their immediate proximity, but not necessarily across an entire room.

When used in conjunction with targeted air movement and interaction with an existing HVAC system, they could be highly effective. However, often the volume of the room is compared with the output of the unit and the statement is made that the room is cleaned in X number of minutes! In reality the clean-up rate depends entirely on the airflow pattern in the room, and a single point discharge of clean air is unlikely to reach and clean all corners of the space.

UV lights

The issues with UV lights are well documented. UV lights are highly effective as long as the contaminant in question gets a direct dose at a high incidence angle. Obviously it is not practical to thoroughly irradiate an occupied room. Some systems radiate UV at a high level but, in reality, what is the number of contaminants that would actually make it up to that section of the room, particularly a mechanically ventilated one? (Note the epilogue – perhaps more than we think.)

The use of UV in ductwork, if through a sufficient length and of a high enough intensity, may be effective, but so is a HEPA filter. In addition, what level of decontamination are we expecting or looking for in an air supply to a public space?

Cleaning

There is no doubt that in public spaces or cleanrooms, physical cleaning is the most effective means of permanently removing contamination from an area. It is not a terribly attractive method – no smooth lines, fancy lights or high technology, just a procedure, some equipment and chemicals and people.

To be truly effective we need a way to get the contamination out of people's breathing zones and then, as frequently as possible, to have it removed by cleaning.

Epilogue

It is interesting to learn how the sanitary engineer William Wells applied the above technology. He was able to prevent measles being transmitted in a classroom by directing air past a UV light. Note that this was in the day before the commercialisation of HEPA filters and of course air conditioning for classrooms, however it is interesting to read how airflow was described:[4]

"There is no system of ventilation other than windows, and the lower portion of the room thus ventilates to the upper irradiated only by natural convection currents."

Simply put, in an unventilated room natural convection draws contaminated air upwards which is irradiated by the UV light.

References:

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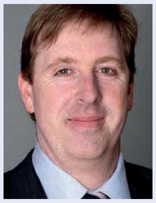

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