**ENVIRONMENT AND MODELLING GROUP**

# Principles of understanding of transmission routes to inform risk assessment and mitigation strategies

**(Based on available evidence up to 05/05/20)**

## Key points

- We propose a framework for evaluating the behavioural, viral and environmental factors that control the transmission of SARS-CoV-2;
- The approach can form the basis of quantitative assessment of transmission risk, however there is insufficient data available to currently do this with confidence. Research to quantify factors that determine transmission should be prioritised to enable this environmental level assessment to be carried out.
- The approach can be used now to inform structured risk assessments that consider the transmission mechanisms against a hierarchy of risk controls. We recommend this is used to consider risk during different job activities to identify key points for mitigating risk.
- It is essential that risk reduction interventions use a "mitigate, monitor, modify" approach that is supported with national surveillance, test-trace-isolate, targeted research programmes and local monitoring approaches. Critically, reactive intervention studies are urgently needed to address critical evidence gaps in support of a sustainable return to work strategy.

## Executive Summary


- The risk of contracting and transmitting SARS-CoV-2 through surface contact, short-range (person-to-person) exposure and the air can be evaluated using a Quantitative Microbial Risk Assessment (QMRA) framework. This approach enables quantitative assessment of the relative importance of different transmission routes as well as the effect of mitigation strategies.
- There is currently insufficient data on the parameters that determine transmission to reliably use this approach in a quantitative way. There is significant uncertainty around the relative contribution of different transmission routes (surface contact, short-range person-to-person, airborne) and the dose of SARS-CoV-2 that is needed to cause infection. Research programmes and epidemiological investigations are needed urgently to address this gap.
- The approach does currently enable identification of the main factors that are believed to influence the transmission of disease. This enables a framework for mapping how mitigation measures will interrupt the transmission of the virus. This approach can form the basis of a structured, pragmatic risk assessment.
- The approach to controlling risk should be based on the well-established hierarchy of control; mitigation measures that are implemented at a system or organisational level should be applied as far as possible before implementing those that rely more heavily upon individuals taking control.
- We propose that assessment of risk should be based on the likely exposure during the range of activities carried out over a work day. This will give a better understanding of where there are specific risks for someone to transmit the disease or for being exposed to disease than just considering the overall work environment.

- To build an evidence base and identify problems it is important that data collection should be built into any risk reduction interventions using a "mitigate, monitor, modify" strategy to adapt to changes in evidence.
- All of the transmission routes are influenced by the prevalence of virus within the population, with a higher prevalence increasing the likelihood that someone will be exposed to a level of virus above the infectious dose. Strategies to reduce population level exposure such as work from home and test-trace-isolate should remain as very high priorities for control.
- We strongly recommend that national surveillance systems and research programmes are set up to collect data on occupation and location of positive COVID cases in order to identify those roles and environments where controls are effective and where they can be improved (e.g. hospital admissions, environmental sampling, test-trace-isolate). We also recommend that research programmes should collect data that allows linking between prevalence of virus in the workplace, controls implemented and the behaviour of those in the environment.
- At national level, the likely impact of mitigations on the whole system risk should be taken into account (e.g. implications for transport, system of opening schools).
- It is important that vulnerable groups as well as equality and accessibility are considered throughout the risk assessment process.

## Detailed Principles and Evidence Summary

### Introduction

1. To understand and effectively control transmission of SARS-CoV-2 it is necessary to identify and quantify the factors that determine the exposure risk via each of the potential transmission routes:
    a. Exposure to SARS-CoV-2 from surfaces (contact transmission);
    b. Exposure to SARS-CoV-2 from people (short range droplet transmission);
    c. Exposure to SARS-CoV-2 from the air (aerosol transmission);

   For all these routes the risk of infection is determined by the amount of virus present, the duration of exposure and the dose-response.

2. Risk assessment comprises **risk estimation**, '*how big is the risk of what to whom?*', and **risk evaluation**, '*are the risks tolerable?*' Risk estimation can be qualitative, semi-qualitative, or quantitative: the appropriate approach depends on the nature of the risk, the degree of uncertainty in evidence about that risk, and who is doing the risk assessment.

3. While there are studies that quantify transmission risk for respiratory diseases, these primarily focus on modelling exposure and subsequent risk of infection through an airborne route [1]. Frameworks for considering the role of the environment in infectious disease transmission, particularly where there are multiple and complex transmission routes, have been more widely applied in the water, sanitation and hygiene (WASH) sector. WHO indicate three approaches with increasing complexity that can be applied in the context of waterborne diseases [2]: simple visual inspection of systems to identify failings; using a risk matrix based on understanding of hazards and their likelihood to assign a risk score; using a formal quantitative assessment based on scientific data on transmission parameters. Whichever approach is taken, risk estimation should be structured and systematic.

4. We consider approaches to environmental risk assessment to evaluate how understanding of the factors that influence exposure to SARS-CoV-2 can be used to:
   (i) Develop a framework for quantitatively modelling risk and identify the data that would be needed to do this;
   (ii) Inform the process of identifying appropriate mitigations that will address one or more of the transmission routes;
   (iii) Consider how this can be applied in a workplace context.

## A quantitative microbial risk assessment (QMRA) framework for COVID-19

5. QMRA is a well-established methodology for assessing exposure to pathogens, using a probabilistic modelling approach to estimate the transfer of pathogens to people with data on dose-response to calculate risk. The approach is widely applied to water and food borne pathogens [3][2][4], and there is some precedent for application to respiratory pathogens [5], [6][7]. The approach has four stages:

   - Hazard identification – which microorganisms and what diseases they cause
   - Exposure Assessment – quantification of the amount of virus the individual is exposed to, which depends on the amount in the environment and the route of exposure
   - Dose-response – model for the response to a particular dose (possibly for a particular route)which relates the amount of virus an individual receives to the probability of infection
   - Risk characterisation – brings together the exposure and the dose-response to predict likelihood of infection (as a probability). In simple terms this can be expressed as *Risk of infection = Exposure x Dose-response*

6. In the context of COVID-19 we have good evidence to support the first step (hazard identification), and the fourth step (risk characterisation) is feasible through mathematical models. However there is significant uncertainty around exposure assessment and dose-response.

7. It is also feasible to use this to estimate the impact at population level or within a group using the concept of *Impact = Number exposed x Risk of infection x Vulnerability*. Vulnerability here could be the probability of infection translating to either a case requiring hospitalisation or resulting in death (or both). The impact in that case would be the number with that outcome. While not losing sight of the human impact of these outcomes, this approach it would be helpful for weighing up costs and benefits of mitigation measures. The limitation with this approach is that it does not account for the potential for feedback or cross-transmission into other activities. However, this could be addressed by combining impact assessments for different scenarios.

8. This type of quantitative approach has been used previously in a small number of studies to evaluate the potential contribution through different routes of transmission, which potentially gives very valuable insights into the importance of different types of exposures. Of particular relevance are a study to theoretically evaluate routes for influenza exposure [8] and a study that considered comparison of influenza A, SARS-CoV-1 and norovirus in an air cabin[9].

9. *Exposure Assessment* In considering exposure, time is a factor, with an increased likelihood of a higher viral dose when spending a longer period of time with an infected person being a well-recognised risk for most respiratory infections. We are here considering that exposure can be treated as cumulative over a short period of time (a few hours) but not over days. This would assume that someone needs to have sufficient exposure in a relatively short period of time to become infected, and we assume that small doses over a long period (say a week or more) would not lead to infection. We consider the factors (below) that influence each of the transmission routes and how they interact together. Evidence for these factors is within previous EMG papers (14/04/20, and EMG Environmental Tranmission 020520).

10. *Dose-Response* The exposure assessment alone can enable an understanding of relative effects of mitigation measures, however to understand infection risk and hence predict the likely impact of changes it is necessary to have data on dose-response. This is a relationship that describes the likelihood of infection from exposure to a particular dose, and can be constructed from data from animal models, human trials and past outbreaks. The dose-response is commonly described with an exponential or beta-Poisson relationship [6]. It is possible that the dose-response will vary with transmission route – for example a disease could need a higher or lower dose to cause infection when delivered as fine particles to the lungs than course particles to the nose. For most diseases this level of detail is not known. Because the dose-response is non-linear, it is not possible to translate relative reductions in dose to relative reductions in risk without its definition.

11. There is not yet a quantified dose-response relationship for SARS-CoV-2, however there is a curve for SARS-CoV-1 [10] which follows an exponential relationship. For airborne transmission the Wells-Riley model [11] is commonly used which is an exponential relationship using a term "quanta" to represent the infectious dose and this has been applied to an airborne outbreak of SARS-CoV-1 [12]. While this is cruder than a dose-response model, it is a way to estimate risk of infection based on past outbreak data. It is important that research to determine a dose-response for SARS-CoV-2 is carried out urgently to be able to estimate risk.

12. We would also have to consider how to combine the risks through different routes, and whether we could assume the same dose-response relationship for different transmission routes. Research modelling the virus within the human body may support this question and should be carried out.

13. All of the transmission routes detailed below will be influenced by the proportion of people within a population who are infected. A small number of infected people in a space will lead to a low risk that the air in a building contains virus or that surfaces are contaminated. In this case the exposure may remain below the infectious dose even though there may be virus present. As the proportion of infected people increases the prevalence of virus in the environment is likely to increase and it becomes more likely that exposure is above the infectious dose threshold. While this threshold is currently unknown, this is an important principle in mitigation, with actions to reduce the likelihood of infectious people being present at the heart of mitigations strategies.

**Contact exposure**

This is assumed to be determined primarily on the amount of contamination on someone's hand. This can be assessed using models such as those defined in [13]

***Hand contamination = amount on surface x number of contacts x area of contact x transfer efficiency x (1-hand hygiene efficiency)***

*Hazard = amount of virus on surface*
*Transfer = number of contacts x area of contact x transfer efficiency x (1-hand hygiene efficiency)*

Hand contamination leads to inoculation through touching face (eyes, mouth, nose), which requires additional data on hand-face touching behaviour.

| | |
|---|---|
| *Amount on surfaces* | Increases with occupancy (more sources ), increases with number of different occupants (higher chance of a source), increases in high touch environment (more touches moves it around), decreases with cleaning frequency, adjusted for material, adjusted for indoor/outdoor, adjusted for temp & RH & UV, surface type, decreases with time since first contamination and last occupation. |
| *Number of contacts* | For the receptor the dose increases with number of different surfaces/objects touched, increases with frequency of contact. An infectious person would also contaminate a surface at a higher rate with increased touch raising the amount on the surfaces. |
| *Area of contact* | Varies from whole hand (grab handle) to finger (button). The contact pressure may also be an influence. |
| *Transfer efficiency* | Two efficiencies, one for pick up and one for put down, Depends on pathogen, pathogen suspension fluid, surface material, temp/RH, whether hand is gloved or bare. Transfer efficiency is determined experimentally in small scale laboratory conditions for different pathogens/surfaces. |
| *Hand hygiene* | Increases with frequency, increases with effectiveness, depends on method. |

Of these factors, there is existing data from behavioural/observation studies on hand hygiene and hand contact areas that can be used in models, and there is some data on touch frequency with surfaces and hand-to-face. Further data on this is relatively easy to collect through observational studies. Transfer efficiency is microorganism and surface specific; some data exists for bacterial pathogens and influenza that could be used as a first estimate, but data for SARS-CoV-2 is needed to estimate this correctly. The biggest data gap and probably the most important factor in assessing the contact risk is the amount on the surface. There is emerging lab data on surface survival and the influence of environmental parameters, and a small amount of data from sampling in healthcare environments. However there is almost no data on the concentrations on surfaces in the wider environment.

**Short Range Respiratory exposure (<2 m)**

This is assumed to be the immediate exposure that someone would experience while face-to-face with an infected person or when exposed directly to an environmental generation (e.g. a toilet flush). This is taken as the exposure through droplets that land on the mucous membranes, plus aerosols that are inhaled within close range. Contact through surfaces is not included – this is under contact transmission above.

***Amount of virus = droplet deposition onto persons face + short range aerosol inhalation***

***= (droplet generation + (aerosol generation x breathing rate)) x time x (distance relationship) x face-to-face factor***

*Hazard = droplet + aerosol generation*
*Transfer = breathing rate, time x (distance relationship) x face-to-face factor*

| | |
|---|---|
| *Human generation* | Probably increases with loudness of sound, increases with coughing, increases with sneezing, varies between people but can't factor this in. May also vary between languages and even words used. The more virus load within aerosols and droplets, the more likelihood that a particle will contain virus. There may be a relationship between viral load in nasal/throat swabs and droplet/aerosol generation rate |
| *Environmental gen* | Evidence for other diseases that aerosols and droplets can be generated through engineering systems such as toilet/sanitation systems and jet air hand dryers |
| *Breathing rate* | Increases with activity, varies between children/adults and with health |
| *Time* | Increases with both susceptible and infectors duration in the same location |
| *Distance* | Exposure decreases with distance with highest risk up to 2m |
| *Face-to-face factor* | highest for face-to-face, lowest back-to-back, partial risk side to side as people will move their heads, partial risk front-back. May be influenced by relative height of people, may vary for droplet and aerosol component. |

Of all of the transmission routes this is the most challenging to estimate and is a key determinant for both contact and airborne transmission. While there is some data on droplet generation rates from respiratory activities, there is very little data related to respiratory pathogens (only influenza and TB) and no data presently for SARS-CoV-2 or other human coronaviruses. The fate of droplets is discussed in previous EMG papers and is very uncertain, although can be estimated though computational or experimental models from a fluid dynamics/aerosol science perspective. There is very little quantitative data on aerosol or droplet generation from environmental sources.

**Airborne exposure (>2m)**

Airborne transmission is regarded as that which is caused by fine aerosols (< 5µm) which are inhaled at a distance of more than 2m - aerosols that are in the bulk air of an environment rather than at close range.

***Amount inhaled = number of infectors x aerosol generation rate x breathing rate x time x (1/(ventilation rate)+ other losses))***

*Hazard = number of infectors x generation rate*
*Dose= breathing rate x time x (1/(ventilation rate+other losses))*

| | |
|---|---|
| *Number of infectors* | increases with occupancy (more sources ) ,increases with number of different occupants (higher change of a source) |
| *Breathing rate* | Increases with activity, varies between children/adults and with health |
| *Time* | Increases with of both person and infectors duration in the same location |
| *Ventilation rate* | Depends on design of system, for natural ventilation may depend on the weather |
| *Ventilation distribution* | Level of air mixing between zones, layout and mixing devices (e.g. fans, A/C splits). Only influences >2m transmission |
| *Losses* | Loss due to deposition and decay rate of virus in air. May be affected by flow patterns, temperature, humidity, UV, pathogen suspension fluid |
| *Aerosol /droplet gen* | This is as per short range transmission and can be from human or environmental sources |

Estimating this route depends on knowledge of the aerosol source, which is challenging to quantify as indicated above. There is already data on breathing rates which can be used in a model. Ventilation can be modelled though simple zonal models or computational fluid dynamics. Quantifying exposure through this route has some complexities but is likely to be able to be modelled with more confidence than other routes once data on aerosol generation is known.

## Using the framework to inform risk assessment

14. At present it is not feasible to use the framework to carry out quantitative risk assessment with any precision as there is insufficient data available for accurate calculations, as detailed above. However, it is feasible to use the framework to structure assessments of risks and to identify mitigation measures that will address one or more of the transmission routes.

15. Understanding risk is going to be a significant part of a package of measures enabling people to go back to work and wider societal activities to restart. This will need to include consideration of how to protect workers from becoming infected as well as how to prevent spread from infected workers to colleagues, their families and the public. It is important that the assessment of risk considers the potential for exposure to the virus in the context of the transmission routes, and hence the development of a mitigation strategy that is related to these risks.

16. This will be bespoke, not just to a workplace environment but to the people and activities within it. It will be critical to understand the relative risks of the various activities that make up either a job, or a "user journey". Each work activity or element of a user interaction will involve a number of potential exposure routes and risk factors which need to be understood to enable effective control measures to be put in place.

17. Each employment sector, job or user experience is also part of the wider local, regional amd national systems. Changes affecting workers in one work activity may affect the level of transmission at different geographic scales, and affect the ability of the wider system to manage the overall risk effectively. For example, if transmission of SARS-CoV-2 can be controlled effectively in many office spaces, this might lead to an increase in commuting by office workers which might significantly increase the likelihood of transmission through the transport system. The people best placed to assess the risks in any organisational situation are the actors who are required to manage the risks (e.g. the employer). However, there will be a role for central and local government to monitor and review activity as a whole at a national/local level particularly in the context of the impact individual decisions have on the wider system.

18. When estimating the risk posed from SARS-CoV-2 in any work activity or user journey, the following principles provide a systematic approach that can be applied in a qualitative way:
    ***i.*** *Identify the Hazards and Exposure:* The QMRA framework can be used to understand the factors that influence exposure and hence how these may be important in different activities or environments
    *ii.* *Identification of Risk:* To identify where hazards might be encountered, it is important that any job or user journey is broken down into its constituent activities ideally by the people undertaking the work activities. To understand the risk, it is important to consider both the frequency and duration of the potential exposure to SARS-CoV-2. Furthermore, the scale of the risk will vary in different situations. For example, activities which involve contact with the public will have a greater risk than activities involving contact with a team of the same group of work colleagues only. Activities that interact across a wide geographic area will have a greater risk than those that are within a contained local network
    iii. *Identification of Controls:* Once the risk estimate has been identified for each work activity, consideration should be given to the controls that need to be implemented to reduce the risk. The controls should be based on an understanding of the transmission routes and the hierarchy of control (see Annex 1) and the best available evidence, which will evolve as new knowledge is generated.
    iv. *Monitoring and maintenance of controls: Systems* would need to be implemented to ensure that controls remain in place until other more permanent mitigation becomes available. This might include increased maintenance checks, repeated communication campaigns, enforcement activities, training programmes etc. In addition, the use of statistical data to identify at risk population groups as they emerge would be critical to gather information on the efficacy of control measures, both within an organisation and as part of a national data collection. Of particular importance would be the routine collection of occupational data at every opportunity (e.g. as part of hospital admission, under "test, trace, isolate", and through the NHS-App). This type of data is crucial to understand where controls are working

effectively, and if there are any strategies, environments or job roles where controlling transmission is a greater challenge and needs further intervention.

### Identifying mitigation strategies

19. A hierarchy of controls [12] is a widely recognised systematic way to identify and prioritise risk control measures based on how effective different types of control are in reducing risks. Risk reduction measures should be assessed in order of the priority given in the hierarchy; it is not a case of simply jumping to the easiest control measure to implement from the list. This is because The types of control higher up in the hierarchy (Table 1 – Annex 1) are more effective at reducing the risks than those lower down the list.

20. Table 2 (Annex 1) indicates how potential mitigation strategies can be identified and categorised with respect to the hierarchy of risk, transmission routes and risk factors. These are currently identified as those where there is some evidence or precedent for use, but are not ranked in any way according to evidence of their relative effectiveness. These strategies are not necessarily complete, and there may be other mitigations that are also appropriate.

21. Controls should be practical to be implemented and, ideally, should be able to be maintained easily over time. It might be necessary to monitor control effectiveness on a regular basis. This may include effectiveness at reducing transmission through data on infection rates or viral load in the environment as well as compliance/feasibility of a particular strategy. Care is needed to not transfer risks or introduce new risks when considering controls measures. The use of multiple different independent controls give defence in depth through different layers of protection but uncertainty remains about the impact on risk of multiple different controls on behaviour and the extent to which they might be additive or sub-additive.

22. Given the nature of SARS-CoV-2, it is important that any controls are regularly and critically reviewed to take account of the evolving evidence base so that continuous learning and improvement is built in. In addition, consideration should be given to the routine collection of data to increase the knowledge base regarding control measures, this should include a, **“Mitigate, Monitor, Modify”** strategy where the efficacy of planned interventions is properly evaluated against a clearly defined set of criteria.

23. It will only rarely be feasible to eliminate the risk completely. The combination of controls introduced should aim to reduce the risk to as low as reasonably practicable prioritising structural, environmental interventions over individual level ones. If any residual risk is judged to remain after this process is completed (including consideration of “layered controls” [14]) then the hierarchy of control would suggest that appropriate Personal Protective Equipment (PPE) would need to be used to remove exposure. This approach is also consistent with the control banding approach proposed for infectious disease control [15]. It is likely that, from a practical perspective, the hierarchy of control won’t always be used in a traditional sense; multiple different layers of control will have to be adapted going as high up the hierarchy as possibly but PPE will likely remain on the table no matter what – partially for reassurance to people and partially to provide some level of defence in depth.

## Other Considerations in identifying mitigations

24. *System issues*: the implementation of controls at the component level would need to be reviewed in the context of the whole system, Experience suggests that if systems thinking is not applied to the whole work situation, then problems can arise at the interfaces between the components e.g. "social bonding" activities at the end of a shift. A positive action in one part of the system may lead to negative consequences in other components of that system. For example, if schools return there will be increased pressures on the public transport system, which may lead to the inability to maintain controls for other travellers. Systems may also change in other ways, for example with adaptations in response to interventions. It is important to identify potential unintended consequences to allow mitigation or reinforcement of them.

25. *Actions to maintain and adapt control*: these would need to be kept under review as new approaches come on line e.g. antibody testing, new technologies(wearable devices to monitor physical distancing). The use of test, trace and isolate strategies are critical to mitigating the population level prevalence and hence the likelihood of viral exposure in an environment. With accompanying advice to individuals the strategy may also support the control of risk at the individual level. This would be particularly true once antibody status can be reliably determined. This could lead to the development of appropriate health surveillance systems for workplaces. There should be a systematic process for capturing data as lockdown is eased. This includes quality statistical information regarding any emerging occupational risk factors. Learning from industries which have continued to operate (chemicals industry, refineries, some retail) is critical, and the opportunity to collect occupational data at any point should be encouraged. Targeted data collection could be considered to address evidence gaps, including regular testing of people and workplaces during any return to work activity. "Mitigate, Monitor, Modify" could be used as a strategy to target resources to fill evidence gaps.

26. *At-risk groups, accessibility and equality*: the process described above provides a "population" based approach to assessing risk. However, there are a number of individual susceptibility issues which would need to be considered at the organisational and national level to ensure that any at risk groups are effectively protected. There is already evidence that COVID-19 has disproportionate impacts across society serving to widen existing inequalities in health and financial resources. It is important to consider equality and accessibility throughout the process to ensure that mitigation strategies do not further marginalise or disadvantage any groups. and that interventions are in keeping with the Equality Act.

27. *Behavioural responses:* These will influence the effectiveness of many of the measures in reducing infection and transmission. In some situations, the introduction of one measure such as wearing of face coverings on public transport might increase physical distancing (by signalling the need for protective behaviours), decrease it (by "risk compensation") or have no effect. In other situations, behavioural responses may result in a failure of control. For example, in the transport sector, intoxication and school traffic have all been highlighted as concerns. Perceived risk is also a concern. Comparison of levels of risk to those accepted within cultural norms (e.g. driving or supermarket shopping during the current situation) may be helpful.

28. *Evidence base for controls:* The nature and novelty of the virus is such that there are many gaps in our understanding of mitigation, and therefore in our ability to access an evidence base on a wide range of potential controls employed on their own or together in combination. EMG is currently reviewing the evidence base for environmental controls and aims to share more comprehensive information where this is available. Research studies assessing the effectiveness of control strategies across a range of organisations are strongly recommended to build the evidence base.

29. *Longer term approaches*: In mapping the current controls, many that can be implemented quickly sit within the “administrative” band of the hierarchy of control. There is a need to take a longer-term view - given elimination of SARS-CoV-2 is unlikely before a vaccine - to develop a wider range of robust elimination, substitution and low cost engineering controls which meet the requirements of specific control needs.

30. *Risk communication*: This should be used as a way of empowering individuals to make informed decisions about their own protection as well as well as the protection of others. This can allow individuals and organisations to better judge the relative safety of different activities and environments including returning to work. . If they understand the principles by which risk can be controlled then they may be able to support the process through a dynamic individual assessment of their personal risk in any situation.. We recommend the development of approaches for effective communication of risks to enable individuals to better judge the relative safety of environments and how their own behaviour within these spaces can positively contribute to that.

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**ANNEX 1**

**Table 1:** Principle of the hierarchy of control for risk assessment

| | | |
|---|---|---|
| **Elimination** | Redesign the activity such that the risk is removed or eliminated | Most effective – removes exposure |
| **Substitution** | Replace the activity with an activity that reduces the risk. Care is required to avoid introducing new hazards from the substitution. | ↑ |
| **Engineering Controls** | Design measures that help control or mitigate risks, such as barriers, guards, etc. Priority should be given to measures that provide collective protection rather than those that just protect individuals or a small group of people. | Increasing effectiveness |
| **Administrative Controls** | Identifying and implementing the procedures to improve safety, such as undertaking risk assessments, preparing and communicating mitigating procedures, and increasing signage. | |
| **PPE** | Personal Protective Equipment: local kit to mitigate the risks to those exposed to the hazard. People must be familiar with the function and limitation of each item of PPE for this to be an effective measure. Ideally, PPE is only considered after all previous measures higher in the hierarchy are identified as not being fully effective in controlling the risks. | Least effective – relies on personal compliance |

**Table 2:** Mitigation measures associated with transmission routes and risk factors

| **Hierarchy** | **Mitigation** | **Transmission route** | **Risk factor addressed** |
|---|---|---|---|
| Elimination | Stop an activity that is not essential | All | All<br>Note, this should not necessarily be seen as being removed as lockdown is relaxed. At a more granular specific level work activities may removed while other parts of a job continue. |
| | Test, trace, isolate | All | Reduces amount of virus on surfaces and in air<br>Reduces interactions between susceptible and infected |
| Substitution | Changes to shift patterns | All | Time – reduces duration of exposure for susceptible individuals<br>Amount on surface/in air - reduces duration of contamination from infectors |
| | Move to outdoor working | Contact<br>Short Range<br><br>Aerosol | Amount on surface – evidence for higher decay in sunlight<br>Amount in air -evidence for higher decay in sunlight<br>Ventilation rate – higher dilution in outdoor spaces |
| | Changes to or restriction of "loud" activities (e.g. reduce talking time, no singing) | Short range<br><br>Aerosol | Amount of virus generated – evidence that loud talking and singing produces higher number of aerosols and droplets |
| Engineering | Low (or no) touch surfaces | Contact | Reduces number of contacts with contaminated surfaces |
| | Anti-microbial surfaces | Contact | Amount on surface – increases decay rate of virus |
| | Provision of hand wash stations | Contact | Hand hygiene – decreases amount on hands after exposure |
| | Replacement of jet air dryers with paper towels | All | Hand hygiene – decreases amount on hands after exposure<br>Amount on surface – decreases contamination rate through droplets<br>Amount in air – decreases environmental aerosol potential |

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| | | | NOTE this may create contaminated waste which could *increase* contact risk if handled incorrectly |
| | Exposure to UV light (disinfection/ decontamination units). Daylight in buildings may also be beneficial. | Contact<br><br>Aerosol | Amount on surface –increase decay rate of virus<br>Amount in air – increase decay rate of virus |
| | Automated systems (e.g. payment) | Short range | Reduce number of face-to-face interactions. NOTE this could *increase* contact risks unless other mitigations are put in place such as contactless technologies |
| | Screens/barriers | Short range | Amount of viral exposure – blocks transport of droplets from infected to susceptible |
| | Good maintenance of sanitation systems | All | Amount of viral exposure – reduces contamination of air and surfaces |
| | Increased fresh air ventilation rate | Aerosol<br><br>(Contact) | Reduces amount of virus in air – quicker dilution<br>May have a small benefit in reducing surface contamination |
| | Change in air distribution (local extract, pressure controls, ventilation pattern) | Aerosol<br><br><br>(Contact) | Reduces exposure to virus in air – prevents virus being dispersed within and between spaces<br>May have a small benefit in reducing surface contamination |
| | Air cleaning devices | Aerosol<br><br>(Contact) | Reduces amount of virus in air – removes or inactivates virus<br>May have a small benefit in reducing surface contamination |
| Administration | Frequency and effectiveness of cleaning of surfaces | Contact | Reduces amount on surface, reduces duration of time that a surface is contaminated |
| | Provision of hand sanitizer | Contact | Hand hygiene – decreases amount on hands after exposure |
| | Changes to touch behaviours | Contact | Reduces number of contacts with contaminated surfaces, reduces |

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| | (e.g. education programmes) | Short range | face/fomite touching if hands are contaminated |
| | Hand hygiene promotion | Contact | Hand hygiene – improves frequency and effectiveness of handwashing |
| | Control of occupancy density | All | Reduces probability of an infector being present, reduces number of susceptible people available |
| | Distancing between people | Short range | Distance factor - reduces probability of being exposed to a high viral load |
| | Orientation of people | Short range | Face-to-face factor – reduces probability of being exposed to a high viral load |
| PPE | Gloves | Contact | Hand hygiene – reduces chance of hands being contaminated. NOTE gloves can become contaminated and hand contamination can occur during removal |
| | Protective clothing | Contact | Reduces chance of hand contamination following touching clothing. NOTE this is only effective if protective clothing is removed correctly and other hygiene procedures followed. |
| | Face masks/respirators on individuals exposed to aerosol generating procedures | | Reduces potential for droplet exposure through nasal membranes. Will also result in small reduction in inhalation risks if work correctly and fit tested where appropriate |
| | Face shields/goggles | Short range | Reduces potential for droplet exposure through eyes for goggles and nasal membranes and some inhalation for shields |

NB: Face coverings may be worn as a means of preventing asymptomatic individuals from transmitting virus via the respiratory route (if both nose and mouth are covered). There is little evidence that face coverings prevent wearers from being exposed by others.