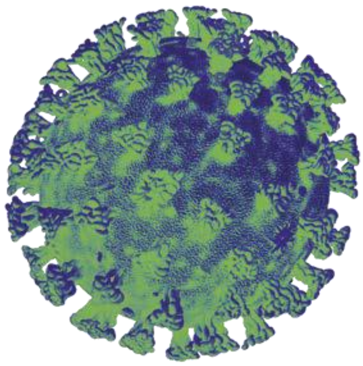
Llywodraeth Cymru
Welsh Government

Technical Advisory Group

Reducing COVID-19 transmission in schools and colleges: the role of air cleaning devices amongst other mitigations

21 January 2022



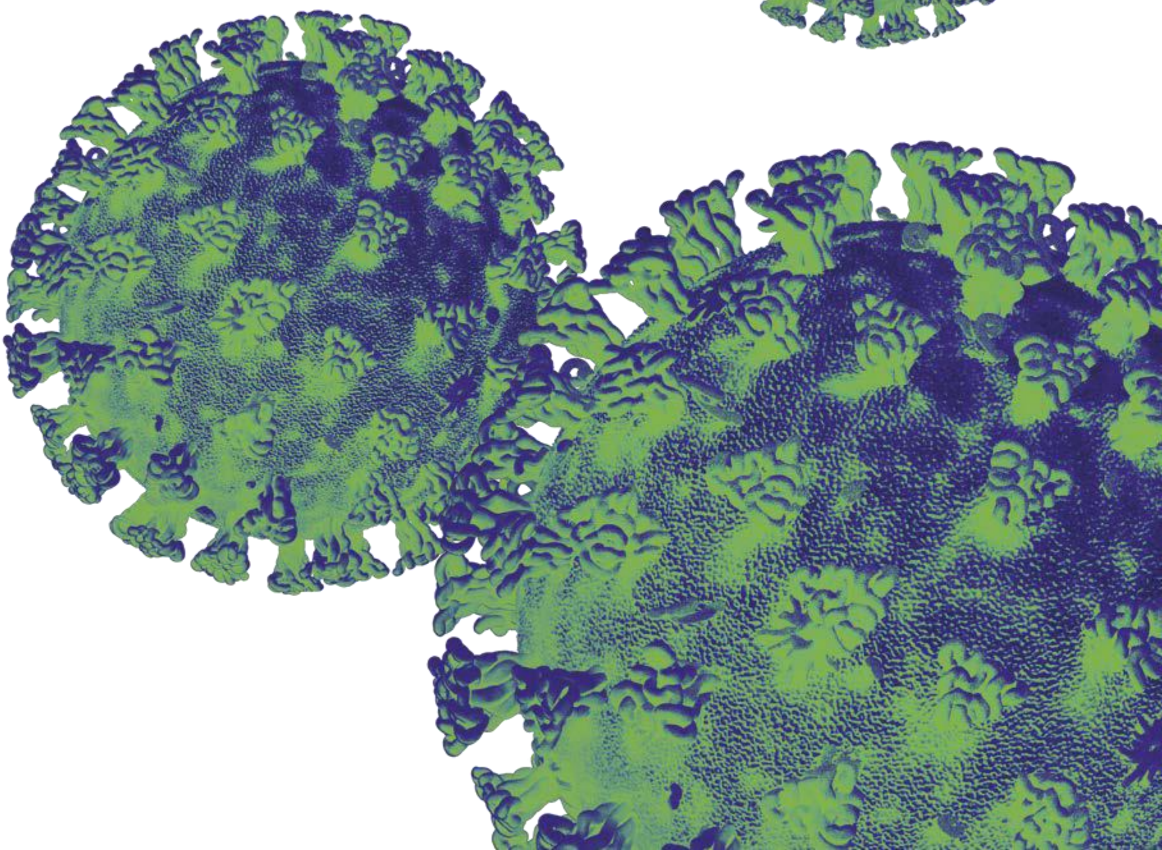


Table of contents

1. Summary of high confidence conclusions

1.1 The Education and Public Services Group at the Welsh Government commissioned this advice from the Technical Advisory Group Environmental Sub-group (TAG-E), requesting a review of

- current evidence all systems available to improve air quality in the built environment;
- the appropriateness of using these systems in education settings;
- a minimum specification for any type of system approved, with clear identification of where the system sits in the hierarchy of control measures.

1.2 There is a substantial body of evidence-based practical guidance for managing and improving ventilation and indoor air quality (IAQ) for the built environment such as that published by the Health and Safety Executive (HSE), the Chartered Institution of Building Services Engineers (CIBSE) and in the *Building Bulletin 101: guidelines on ventilation thermal comfort and indoor air quality in schools*, published by the Education for Skills Funding Agency (applicable in Wales). There are also standards published by the British Standards Institution (BSI) which can apply.

1.3 This paper does not rehearse existing guidance in detail. Rather, it concentrates on the role air purifiers can play to improve poor ventilation when other mitigations are ineffective, in schools, colleges and universities.

1.4 This review builds on the 2021 paper *Air cleaning devices* published by TAG-E at

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1.5 The conclusions are:

- Air purifiers should be used to supplement other safety measures such as masks, screens and social distancing but not to replace them since the reduction in infection risk is modest compared to these other interventions (Curtius *et al.*, 2021; Zacharias *et al.*, 2021).

- Rooms that are poorly ventilated may reach acceptable safety if an appropriate air purifier is used. For example, in an average classroom with poor ventilation, a strong air purifier (with a clean air delivery rate (CADR) of around 1,000m^3/h) can increase the effective air changes per hour (ACH) from 0.72 to 6, in line with ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) recommendations (Curtius *et al.*, 2021; Pretty *et al.*, 2022).

- Most studies (with strong purifiers) report significant concentration reduction at all locations measured, such as halving the particle concentrations in 6-15 minutes (Kahler *et al.*,2020) and reduction by a factor of six in the inhaled dose over two hours (Curtius *et al.*, 2021).

- In some cases, increased concentration at some locations was observed within the first 20 minutes (Dbouk & Drikakis, 2020; Burgmann & Janoske, 2021). This is consistent with the findings of our original research (Pretty *et al.*, 2022).

- Existing research suggests that strong purifiers (CADR greater than 1,000m^3/h) are the most appropriate for classrooms, although they are noisy; detailed consideration of the noise is outside of the scope of this work. Further research is required to determine whether use of multiple weaker (quieter) purifiers is a viable alternative.

- Optimal positioning of an air purifier (or several purifiers) depends on the locations of people, furniture and the air cleaning device in the room; the airflow generated by the ventilation system; and the airflow generated by the purifier. Determining the optimal positioning of purifiers requires further research and will differ depending on the details of the indoor space of interest (Zhai *et al.*, 2021).

2 Current evidence of systems available to improve air quality in the built environment

2.1 Key points

- Provision of fresh, clean air is the most effective method to improve indoor air quality. Ventilation standards are covered comprehensively in existing guidance. Air cleaning devices are not a substitute for ventilation (HSE, 2021b) but can help to mitigate poor ventilation.

- The most researched air cleaning devices use high-efficiency particulate air (HEPA) filters to remove viral (and other) particles.

- There are other methods of air purification that are less common in commercial air purifiers and less well researched. Of increasing scientific interest is the use of ultraviolet (UV) light to deactivate the virus particles found in the air and on surfaces. Another type of air purifier is an air ioniser. Neither of these types of device are as thoroughly researched as filtration-based purifiers to remove microbial contaminants.

- It should be noted that the Scientific Advisory Group for Emergencies (SAGE, 2020) advises

  > *Devices based on other technologies (ionisers, plasma, chemical oxidation, photocatalytic oxidation, electrostatic precipitation) have a limited evidence base that demonstrates effectiveness against SARS-CoV-2 and/or may generate undesirable secondary chemical products that could lead to health effects such as respiratory or skin irritation (medium confidence). These devices are therefore not recommended unless their safety and efficacy can be unequivocally and scientifically demonstrated by relevant test data.*

- There is a standard for permissible UV exposure from devices inside ventilation systems (BSI, 2016) and there is guidance for use of UV with adults in the workplace (HSE, 2010). There is no corresponding guidance for children or young people, which precludes the use of UV in ventilation systems in schools, in case of accidental exposure due to equipment failure.

- Powerful (strong) air purifiers with CADR around 1,000m^3/h increase the air exchange rate of a room and reduce the concentration of viral particles significantly. Weaker air purifiers with CADR around 100m^3/h are, unsurprisingly, less effective.

3 The appropriateness of using these systems in education settings

3.1 **Key points**

- Many of the experimental and computational flow dynamics (CFD) studies focusing on classrooms (Burgmann & Janoske, 2021; Narayanan & Yang, 2021; Curtius *et al.*, 2021; He *et al.*, 2021; Kahler *et al.*, 2020) report that air purifiers are effective in this setting provided the purifier is of an appropriate strength and placement is sensible (i.e. the purifier is not placed behind or under furniture).

- While a weak air purifier had only a small impact on infection risk (Pretty *et al.*, 2022), it is possible that the use of multiple small air purifiers in a classroom is a logical solution that may reduce noise and disruption compared to the stronger, larger type. However, both implementation and maintenance costs will be increased by the use of multiple air purifiers so a cost/benefit analysis should be carried out comparing the use of multiple weak purifiers with a single strong purifier.

4. A minimum specification for any type of system approved, with clear identification of where the system sits in the hierarchy of control measures.

4.1 A minimum specification

4.1.1 Key points

- Both the existing and original research suggests that air purifiers (CADR around 1,000m^3/h) can be effective in classrooms as they increase the effective air changes per hour (ACH) in line with ASHRAE recommendation (Pretty *et al.*, 2022).

- While it was seen that a single weak purifier with CADR less than 100m^3/h has only a small impact in reducing infection risk, the possibility of using many such purifiers as an alternative to the large but noisy strong purifier was not explored.

- Most studies report that air purifiers are particularly effective when placed near the infected person. Since it is generally not known who is infected, this is not a practical suggestion outside healthcare settings. Nonetheless, the increased vocalisation and activity of a teacher relative to a typical class means that they may pose a higher transmission risk if unknowingly infected. Placing the device between the teacher and class should be considered.

- Different studies suggest different purifier placements for optimal removal of microbial contaminants: Kahler *et al.* (2020) suggest placing the air purifier in the middle of the longest side of the room. Narayanan & Yang (2021) recommend a position where the exhaust flow aids in the natural recirculation of the room and He *et al.* (2021) suggest placement near the horizontal unit ventilator already in the classroom. Original research also suggests that purifiers are most effective when the airflow associated with the room's ventilation helps to carry viral aerosols into the device (Pretty *et al.*, 2022).

- Each space is unique, and thus, requires individualized investigation of appropriate purifier number, capacities, and locations (Zhai *et al.,* 2021).

- ASHRAE recommendations on positioning of air purifiers include: ensuring the inlet/exhaust is not impeded (e.g. by furniture); using ductwork where possible to direct inlet/exhaust strategically (including expelling the cleaned air outside of the room); and to avoid placement that causes strong air currents between individuals or that blows particles onto surfaces (AHSRAE Epidemic Taskforce, 2021).

4.1.2 The Department for Education (DfE, 2021) in the UK Government has recently awarded a contract to supply air purifiers for use in schools. The Department received input from experts in the field when drafting the specification.

4.1.3 The specification covers three sizes of room and requires the air filtration units to comply with recognised standards for noise levels and filtration performance. It permits use of UV in an air purifier if it is compliant with recognised standards. A supply of filters is included, based on eight hours' use a day.

4.1 The hierarchy of control measures

4.2.1 Key points

- **Elimination** of the risk of infection. Measures include being vaccinated; being tested in line with current recommendations, and self-isolating for the recommended period after testing positive.
- **Substitution** to replace a hazardous activity with a less hazardous one. Measures include managing contact with other people and using outdoor space.
- **Engineering controls** to reduce exposure to the hazard. Measures include increased ventilation; introducing one-way systems in a building; observing social distancing, and effective communication about how people can reduce their risk (which includes encouraging them to get vaccinated).
- **Administrative controls** to change the way people work. Measures include working from home (where possible); facilitating hand hygiene, and cleaning.
- **Personal protective equipment** (PPE) to protect people from residual exposure. Measures include providing and ensuring the use of appropriate face coverings and other PPE.

(Welsh Government, 2021b)

4.2.2 There is a series of measures to promote improved IAQ, especially to reduce and remove harmful biological agents such as viruses. Controlling IAQ is itself one step in a wider series of measures to prevent infection particularly in the context of the COVID-19 pandemic, many of which are stronger mitigations than managing IAQ by ventilation or air cleaning. They comprise: being vaccinated, testing for the presence of the virus, ensuring the absence of infected people, observing social distancing of at least 2m, wearing appropriate masks, and maintaining hand hygiene.

4.2.3 An ideal testing strategy would ensure that all infected individuals are identified and self-isolate, thus reducing the risk of infection. If however there is still a possibility that infected individuals may be present - for example, when prevalence is high - having multiple purifiers offers the potential of mitigating transmission from multiple point sources, especially if there is uncertainty as to the position of the infected person or persons. This merits further investigation.

4.2.4 Guidance issued by the Welsh Government (2021b) contains a hierarchy of measures to reduce the risk of COVID-19 transmission in schools); see paragraph 4.2.1.

4.2.5 Ventilation is important because of the risk posed by airborne viral particles present in aerosols and droplets (Qian *et al*., 2021). Measures to specifically improve ventilation can be summarised as follows (Scottish Government, 2021b):

1. Ensure flow of fresh air to remove viral particles and other contaminants (natural or mechanical), whilst considering thermal comfort.
    a. Natural - open windows/doors- a little for a little while if cold - and during breaks and lunchtime
    b. Mechanical – ensure set for optimal performance
2. Use CO_2 monitors to identify poorly-ventilated spaces (multiple readings over time).
3. Ventilate the empty room regardless of thermal comfort if other measures have no effect.
4. If ventilation cannot be improved sufficiently and use of the space must continue, use an air cleaning device.
5. Use any poorly-ventilated room as little as possible and for short periods of time only.
6. Stop using the room entirely until it can be remedied.

4.2.6 Most studies emphasise that the use of air purifiers should be a supplementary measure, in addition to other precautions such as masks and social distancing (such as the experimental studies by Zacharias *et al*., 2021; Curtius *et al*., 2021).

4.2.7 When reviewing a range of measures for schools, Kahler *et al*. (2020) recommend air purifiers as the most effective means of reducing indirect transmission (via aerosols) and the use of Perspex screens to reduce direct transmission (via large droplets and surfaces). There is some evidence however that screens could increase risks of aerosol transmission due to blocking or changing airflow or by creating zones of poor air circulation behind screens (Environmental Modelling Group (EMG), 2021).

4.2.8 Using numerical simulations, He *et al*. (2021) compare the use of an air purifier with the equivalent increase in air exchange of the in-built ventilation using CFD and recommend the former, whereas the more recent experimental work of Choe *et al*. (2022) recommends improved ventilation over purifiers as a more long-term solution, since purifiers do not remove carbon dioxide (CO_2) from the room so do not improve the overall air quality.

4.2.9 Preliminary original research found that a strong purifier was more effective than masks or an equivalent increase in the room ventilation when both the infected and susceptible individuals are 1m away from the purifier (Figure 4, Pretty *et al*., 2022). The impact on infection risk when one or both individuals are located further away is not known, but is important in understanding purifiers in the hierarchy of control measures.

4.2.10 In recent work by Moore *et al.* (2021), an algorithm for ranking the effectiveness of various control measures has been developed (as well as an interactive app for policymakers). For example, they have shown that improving ventilation and using masks is more effective than frequent lateral flow device testing (LFD). The algorithm could be adapted to compare more control measures, including air cleaning devices.

4.2.11 In winter, increasing ventilation to reduce exposure to disease must be balanced against the increased energy required and the impact on thermal comfort (CIBSE, 2021b). One measure to mitigate any reduced thermal comfort is to relax the dress code in the workplace or educational setting so that building occupants can dress warmly. Being considerate of user comfort can increase adherence to the actions necessary to reduce the risk of COVID-19 transmission (Scottish Government, 2021a). If having windows wide open would make a room too uncomfortable, leaving windows slightly open for long periods to allow cross-ventilation still improves ventilation, as does opening high windows instead of low, if possible (CIBSE, 2021b). This can be effective even if the windows are all on the same side. Security should also be considered when opening windows and doors. Fire doors should not be kept open in an attempt to improve ventilation, unless fitted with automatic closers so that they function as intended if there is a fire (CIBSE, 2021b).

4.2.12 The Welsh Government has issued guidance to schools and colleges in Wales which requires them to carry out a COVID-19 risk assessment, and contains practical advice to improve ventilation and thus increase the IAQ (Welsh Government, 2021a, b).

4.2.13 Ventilation reduces the risk of infection as good airflow dilutes the concentration of infectious viral particles in the air and can remove them. Ventilation can enhance the reservoir effect, where, in larger spaces, it takes longer for viral particles to disperse through the air, thus reducing the risk of infection (CIBSE, 2021a). Recirculation does not introduce fresh air but moves air and any contaminants present such as viral particles around the space. Recirculation between spaces should therefore be avoided (HSE, 2021b). If there is no alternative, recirculation in a single room is acceptable of there is access to fresh air from outside (CIBSE, 2021b).

4.2.14 The Welsh Government has provided CO_2 monitors and guidance for their use to schools and colleges (Welsh Government, 2021a.) Schools and colleges are advised to take both immediate and longer-term remedial action if the CO_2 levels in a room persistently exceed 1500 parts per million (ppm). Although CO_2 levels can be used to indicate a lack of ventilation, they are not a proxy for the levels of airborne viral particles and cannot therefore reflect the impact of mitigations intended to reduce them (CIBSE, 2021b).

4.2.15 The impact of a poorly-ventilated space can be mitigated by reducing the number of people who use it; limiting the time spent there, and avoiding activities which lead to greater volumes of exhaled air such as exercise or singing, (HSE, 2021a). In addition, wearing masks could reduce the risk of infection.

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