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# Office and Retail

LITERATURE REVIEW MAY 2020

# 1 Abstract

Pollution is the largest environmental cause of disease and premature death globally with air pollution, in particular, taking centre stage as the most prolific contributor[1]. Low air quality caused by air pollution is widely known to be harmful to the lungs and airways, it is capable of damaging almost every organ in the human body. It is estimated that about 500,000 lung cancer deaths can be attributed to air pollution globally, in addition to 19% of all cardiovascular deaths and 21% of stroke deaths[2]. Importantly, air pollution indoors can be up to 5 times worse than the air found outside, according to the EPA[3], thus low air quality is a very serious public health problem[4]. As the British Lung Foundation writes, "We spend about 90% of our time indoors[5]" – at home, school, the workplaces, gyms, restaurants, shops, or elsewhere. Resultantly, during such time, we are likely putting ourselves directly in harm's way. Such damaging consequences of such a phenomenon is widely considered in scientific literature and is colloquially known to cause 'sick building syndrome'.

In the context of the ongoing COVID-19 pandemic, concerns about air quality, particularly within public indoor settings is a global public health concern[6]. Many studies indicate that poor indoor air quality may lead to a range of harmful infections [7] [8]. Airborne 'pathogens' (often released when an individual sneeze, coughs or even breathes) can become suspended in the air for extended periods due to their extremely small mass. Such 'pathogens' include viruses (such as 'novel coronavirus'), bacteria and Fungi. Scientific studies conducted during the current COVID-19 crisis consider the 'novel coronavirus' as one particularly likely to become transmitted through airborne methods. The virus in question also possesses a very high 'transmissibility' score, meaning it spreads from person to person very effectively. Such attributes strengthen the need for purification of air within the indoor setting as air quality becomes not only a more prominent risk, but also the source of mass public anxiety surrounding their day-to-day activities.

In order to address such concerns, the literature reviews the importance of air purification.


1. Landrigan et al. 2017
2. Schraufnagel et al. 2019
3. EPA. 2020
4. Al Horr et al 2016
5. British Lung Foundation 2020
6. GE et al. 2020
7. Cabo Verde at al 2015
8. Blazejewski et al. 2011

# 2 Air Purification

The provision of fresh air in a room, otherwise known as ventilation, is widely considered to be possible via two main methods- namely, natural ventilation and mechanical ventilation [9]. The former refers to the adoption of practical processes such as opening doors and windows in attempts to lower airborne contagion. This process is generally considered to be only partially effective and suggested for limited-resource settings [10]. Alternatively, 'Mechanical ventilation' is suggested as a much more effective alternative, because natural ventilation can lead to harmful outside pollutants entering the indoor environment, further exacerbating the poor air quality inside [11].

Air purification units, therefore, have been widely credited as the complete solution to indoor air pollution of all types. Due to regulations, such devices are widespread throughout healthcare industries across countries globally, providing purified air to millions of workers and patients worldwide. However, now more than ever, the ability of such technologies to be introduced into commercial buildings provide an easy way to improve public health generally [12], especially during times of high anxiety.

Air purifiers have been proven to be extremely successful in purifying the air by removing dangerous suspended particulates [13], they have also been successful at vastly diminish health risks associated with such poor air quality [14] [15] . This is particularly true of units within which multiple technologies operate synergistically within the unit to purify the air most effectively.

## 2.1 The benefits of air purification

**Scientific literature indicates the following advantages of improving indoor air quality:**

1. **Reducing the transmission of airborne pathogens**

Many viruses (e.g. novel coronavirus) and other pathogens are so small that they are able to remain in the air for extended periods after someone sneezes, coughs or talks. Thus, the removal of such impurities from the air is essential in order to avoid transmission of these tiny 'droplets' from person to person [16]. By introducing air purification, 99.99% of impurities can be eliminated from the air, vastly reducing the risk of transmission[17] . Benefits include the reduction in transmission of infectious disease including viruses, bacteria and fungi[18] , as well as the reduction in health concerns associated with high levels of VOCs or a 'complex combination' of VOCs within the air[19].

9. Srivastava et al. 2015
10. Escombe et al., 2007
11. Al Horr et al. 2016
12. Fiegel et al. 2006
13. Griffiths et al. 2005
14. Boswell et al. 2006
15. Rutala et al. 1995

**2. Improved Cognitive Function**

Numerous studies have affirmed a positive relationship between improved air quality and cognitive functional abilities[21 22]. A 2015 Harvard study saw 24 participants spend 6 full working days in an artificially controlled office environment. Participants were uninformed as to the varying levels of air pollution present within their workspace and were required to undertake tests to evaluate their cognition on various days over the period. The scores resulting from such tests were found to be 61% higher on days where the indoor air quality was good i.e. contained low concentrations of pollutants, as opposed to days during which high concentrations of such pollutants were present[23] .

**3. Improved Productivity**

A paper reviewing the available literature on productivity in relation to air quality found that improvements in indoor air quality by a factor of between 2-7 lead to significantly improved office productivity[24]. Interestingly, even when the air quality is only 'perceived' to be better, levels of effort undertaken by employees on text typing and calculation tasks within an office environment were observed to be significantly higher[25].

**4. Reduced absence of workers from the workplace**

Increased ventilation, allowing for improved circulation and thus improved air quality has been shown to significantly decrease the absence of office workers. One study found that for each 1 l/s increase in ventilation, short term absence (defined as $< 50\%$ of a year) reduced by 2.9% [26].

**5. Improved learning capacity** Low air quality is commonly found within the context of a school setting. This is commonly attributed to efforts surrounding saving energy; however, such negligence should be considered of higher priority given the well-established harmful relationship between poor indoor air quality (IAQ) and a child's ability to learn [27]. Children are also widely considered more vulnerable to environmental pollutants, leading to widespread findings of 'sick building syndrome' throughout school settings [28]. One paper studied classes of 10-year-old children, measuring the impact increased airflow would have on the children's performance of schoolwork. When teachers issued identical performance tasks which mimicked various aspects of school work, a

16. Kutter et al. 2018
17. Fiegel et al. 2006
18. Srivastava et al. 2015
19. Bessonneau et al. 2013
20. Public Health England 2020
21. Fisk et al. 2011
22. Fanger et al. 2006
23. Allen et al. 2016
24. Fanger et al. 2006
25. Wargocki et al. 1999

doubling of air quality within the classroom was seen to increase performance observed by 15%

It is clear, therefore, due to the many prominent benefits of breathing high quality air, that air purification is not a knee-jerk reaction to the ongoing COVID-19 pandemic, but instead is a long-term investment in the health and confidence of workers and the general public utilising an indoor space. Furthermore, studies show that the cost associated with implementing units to improve indoor air quality is far lower than the monetary savings realised from the multiple benefits of improved health, reduced absence and productivity.

## 2.2 What to consider when purchasing an air purification

When it comes to deciding on the appropriate air purification unit, two fundamental considerations are important to consider. Firstly, how well does the unit purify the air; i.e. what proportion of the pollutants are able to be processed and eliminated from the indoor airflow. Secondly, how much air can a unit draw through its internal systems per hour, or simply put - what size room is a unit capable of purifying? This is usually measured in cubic meters per hour. This second consideration is often overlooked, resulting in under-engineered units attempting to purify rooms far beyond their capabilities. This results in a significantly 'over-worked' purifier unit- which will be extremely noisy, need to be constantly replaced and ultimately ineffective at purifying the air.

**How well does the unit purify the indoor air?**

As previously outlined, the contaminants likely to be present in the indoor air of an office, restaurant, gym (or any other public space with regular public usage) are plentiful and potentially include numerous viruses, bacteria, fungi, as well as larger impurities such as dust, pollen and other irritants. As such, the removal of such pathogens requires a combination of filtration and elimination technologies to operate synergistically [29]. Through using a collective combination of the following technologies, and hardwiring them into a single unit, indoor air quality can be significantly improved. Thus, the investment in an effective purification unit can lead to numerous benefits to not only people's health but very importantly, people's sense of well-being and their confidence to return to social settings. Such benefits are seen as particularly important within the current COVID-19 pandemic. Furthermore, the immediate benefits of high-quality air are, as explained, even broader.

26. Fisk et al. 2011
27. Fanger et al. 2006
28. Kishi et al. 2018
29. Wargocki et al. 2005

The necessary technologies, according to the literature, are outlined below:

**Pre-filters**

A pre-filter removes large impurities from the air and acts as an initial purification step prior to subsequent processes. This filter also plays an important role in extending the lifespan of other filters in a device.

**Carbon filters**

Carbon filters (or 'activated carbon') are an advanced type of filter that allow organic compounds to be removed from the air as well as odours and other potentially present gas pollutants[30].

**HEPA (High-Efficiency Particulate Air) Filters**

A HEPA filter is capable, by definition, of capturing at least 99.97% of particulate 0.3 microns in diameter [31]. The filter structure involves an outer filter trapping larger particles, prior to a second filter in which the smaller bacteria and debris are captured. Despite the effectiveness of HEPA filters to capture pollutants, these filters also provide a potential 'breeding ground' for particulates within the unit[32]. Thus, it is crucial for the HEPA within a unit to be coated in an antimicrobial preservative layer, thus inhibiting the growth of bacteria on a filter[33]. Readers should be aware of the marketing tools used by companies to advertise their air purifiers as being "HEPA-type," "HEPA-like," or "99% HEPA," as these refer to HEPA filters which perform below industry standards outlined above[34].

**UV-C Irradiation**

UV light refers to a very powerful light just outside the visible spectrum to humans. Most importantly, however, UV-C can be created artificially by humans and is extremely effective at destroying harmful microbes. This means UV-C can effectively kill bacteria, viruses and mould particles passing through the chamber. Importantly, UV-C emitting bulbs within air purification units are not released externally (outside the constraints of the unit's internal infrastructure) meaning their use is safe to the user.

30. Fiegel et al. 2006
31. Zeng et al 2004
32. Sehulster et al. 2003
33. Chuaybamroong et al 2010
34. Jeong et al. 2019

**Does the device have UV-C capability?**

As previously indicated, due to the vast numbers of potentially harmful pollutants in the air, a combination of the above technologies are necessary to effectively purify indoor air and make it safe for humans to breathe.

One crucial component in particular (UV-C irradiation) remains absent in many purification devices, deeming the effectiveness of such units as sub-par. Without such capabilities, a purifier relies too heavily on trapping particulate matter, as opposed to killing them. For example, despite the effectiveness of a HEPA filter, even at very small impurity levels, these filters do not kill any pathogens. UV-C irradiation involves high-energy wavelengths being emitted via a special UV bulb from deep within in the purifier unit which provides the ability to damaging the genetic material (DNA or RNA) of microorganisms such as bacteria and viruses, deeming them no longer able to perform their vital functions. Such technology, known as 'germicidal irradiation', is an essential part of any full air purification solution and is the most widely adopted method of control for contaminants in US health centres[35]. Many studies confirm the use of this technology an important addition to any purification unit, whilst highlighting that such a process bore no utilisation risk to the user[36].

UV-C capability is also important for a number of other reasons. For instance, viruses are extremely small. The current 'novel coronavirus' for example is between 0.12-0.16 microns in diameter (compare this to the width of a single human hair which measures at least 17 microns across) [37]. Therefore, other filters within a device, such as the HEPA filter will not always be sufficient as a means of purification. UV-C, on the other hand, has proved effective at deactivating such viruses from contaminated air at extremely high efficiency[38]

Readers should also be aware of the positive relationship between the strength of the UV-C bulbs used in the purifier (measured in wattage) and eradication of pollutants. As such, not only is the presence of UV-C capability imperative but also important to consider is the strength of these bulbs. Existing models on the market vary from a low of 10W up to an impressive 24W. The higher the wattage, the greater capability to kill pathogens.

35. Yadav et al. 2015
36. Jafari et al., 2018
37. Green et al., 2001

**What size room is a unit capable of purifying?**

The maximum 'throughput' of a unit dictates the size of the room it is able to purify. This refers to how much air the unit can process and can be summarised by the following metric – 'meter$^3$ per hour'. By calculating the volume of a given room, therefore, you can consider whether a unit is powerful enough to purify the air within it.

Suppose a room you aim to purify is 5 meters wide, 8 meters long and has a ceiling height of 2.5 meters, that would give a total volume of 100m$^3$. We could then assume that a purifier that indicated a potential capability of 100m$^3$ could process and 'turn-over' the air in that room one time per hour. The literature on this subject indicates that in the case of infection transmission via particulates suspended in the air, the more air changes achieved per hour, the lesser the likelihood of possible infection transmission[40].

It is also important that the purifier unit is not running at full capacity indefinitely. Such over-use will lead to increased stress on the machine, leading to issues such as increased repair requirements and unpleasantly high noise levels. As such, it is advisable to purchase a unit capable of throughput far in excess of required capability - thereby allowing the unit to run at a considerable margin below its full capacity and still achieve regular internal purified air changes. Under such a scenario, noise levels shall be much lower and, in many cases, hardly noticeable. Furthermore, the optimum ventilation requirements to prevent airborne infection are unknown in their entirety (although speculated), thus a unit should be capable of exceeding guidelines to future-proof against possible introduction of regulatory guidelines as more research becomes available.

## 2.3 Concluding remarks

This white paper considered research specifically undertaken to evaluate the damaging role of low air quality with indoor environments. Such a field of study is of particular concern during the ongoing 'COVID-19' pandemic, however, the wider health implications of low indoor air quality are extensive and extremely common. In line with the well-researched air-quality solution known as 'mechanical ventilation', this paper takes a more in-depth look at the potential of air purification units to provide a healthier indoor environment. The technologies commonly integrated within such solutions are evaluated both theoretically and practically, with a focus on UV-C irradiation as an essential component of any complete air purification solution. It is the intention of the author that such a paper will allow the reader to make a more informed decision regarding potential solutions available to counter air-quality issues across a number of

39. Ward et al. 2020
40. Kim and Kang 2018
41. Kujundzic et al., 2007
42. Memarzadeh et al. 2011

industries, providing bottom-line benefit to those who invest in such technology. It is essential to consider such purifiers as a long-term investment and not merely a knee jerk reaction to COVID-19- as the benefits they achieve extend far beyond virus protection. Further, the ultimate goal of this paper is to contribute towards overall improved indoor air quality and for the benefits of such to be widely realised.

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