# OPTIMISING YOUR ENVIRONMENT FOR MAXIMUM PERFORMANCE.

SciVision

medicair

A BRYANT MEDICAL PRODUCT


medicair

# 01. PERFORMANCE

Many studies have shown that gym users become increasingly susceptible to contaminated air during exercise. Workouts encourage individuals to breathe through their mouth, as opposed to the nasalpassage, thus encouraging particulate matter to become deposited in the deeper and smaller passageways of an individual's lungs, the areas associated with the greatest risk of infection transmission. Studies have found that those engaging in more intense exercise inhale between 40-80% more contaminants. Even 'moderate intensity' exercise encourages particulate deposition within airways of up to 5x more than someone present within the same setting but not exercising.

# 02. RECOVERY

Research shows that during sleep, individuals breathe passively and are exposed to potentially thousands of toxic chemicals suspended within their air for 7-8 hours per day. Studies have observed a clear relationship between particulate matter (PM10) concentrations and the Apnea Hypopnea Index (AHI), showing increased occurrences of sleep apnoea (interruptions of normal breathing) during the sleeping process of those exposed to high levels of contaminants within the bedroom. Poor air quality can, therefore, have detrimental effects upon sleep quality, thus leading to compromised recovery times. Air purification decreases levels of air pollution and therefore improves in-sleep recovery.

# 03. PROTECTION

Studies have found that human occupation within the gym setting leads to a 900% increase in PM10 concentrations as compared to when the gym was closed. This is particularly concerning given that even low levels of contaminants throughout the indoor air are associated with high exposure risks and thus harmful effects on human health. Such an environment provides a particular hotspot for the transmission of viruses, including the SARS-CoV-2 virus responsible for widespread fear. Improving Indoor air quality, therefore, is not only important for prevention of disease, but it also enhances the participant's overall experience within the gym by reducing particulate matter concentrations commonly found within the gym-setting.

# 04.
# TECHNOLOGY

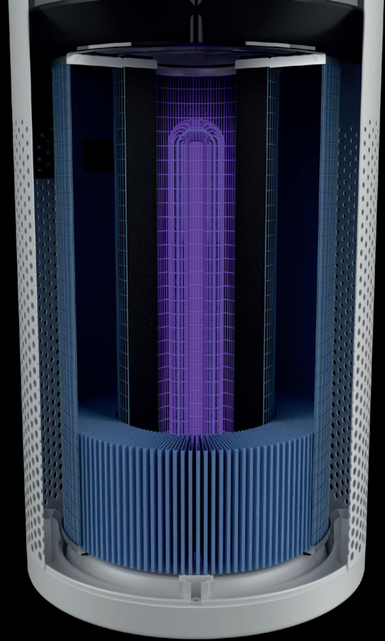
MedicAir® offers a unique solution for purification and filtration of air, improving air quality and reducing the incidence of suspended viruses, bacteria and numerous other harmful contaminants commonly found throughout indoor air.

The MedicAir® unit utilises a custom engineered five-stage air purification process and has a potential throughput of over 600m^3, operating at a maximum of only 60db.

Our innovative ‘ReAKT’ technology system prolongs filter life and our ‘self-change’ filters ensure there are no expensive engineer call-outs for routine maintenance.

Our combination of filters also helps to eliminate odours, formaldehyde and other volatile organic compounds from the indoor setting, providing an enhanced indoor breathing environment.

The anti-bacterial coated HEPA-13 filter has a market-leading 6.7m^2 surface area and filters out 99.97% of all particles down to 0.3 microns, whilst our activated carbon layer removes harmful VOCs and odours, before our 24W virus-killing UVC bulb eliminates viruses and other microscopic contaminants.



# 05.
# ABOUT US

Assembled here in the UK, MedicAir® utilises medical grade purification technology that is used in thousands of hospitals, medical and dental facilities throughout the UK, Europe and Worldwide.

We understand the importance of minimising downtime and respond rapidly to any queries.

**scivisionmedical.com**/medicair


SciVision Medical
South Africa Headquarters
7 Charles de Gaulle Crescent
Centurion, Gauteng,
South Africa

+27 (0)12 665 3541 / 2595

+27 (0)84 405 8025

**E** info@scivisionmedical.com


CE Meets requirements of the Medical Device Directive



ENG

EN1.0CF/BR

SciVision

# MEDICAIR PERFORMANCE LITERATURE REVIEW

### 01. Abstract

Exposure to low indoor air quality (IAQ) is particularly likely within the gym environment for a number of reasons. Firstly, gyms tend to be busy places with high levels of human occupation, one study, for example, found that human occupation within the gym setting led to a 900% increase in PM10 concentrations as compared to when the gym was closed1. Further, particle resuspension is common throughout gyms as surfaces are to be regularly touched in order to allow users to engage in their workout actively[2]. This is particularly concerning given that even low levels of air pollution contaminants are associated with high exposure risks and thus harmful effects on human health[3].
Air Purication has been shown to provide signicant reductions in air contamination, providing air that is healthier to breathe, generating numerous health and performance benefits.

### 02. Susceptibility to poor IAQ within a gym-setting

Many studies have also shown that gym users become increasingly susceptible to contaminated air the more intensely they workout.`The metabolic response to physical exercise exposes the body to the greatest amount of pollutants, since the increase in respiratory ventilation per minute during exercise results in the inhalation of a greater amount of air and consequently of pollutants present in the air'[4].

Workouts encourage individuals to breathe through their mouth, instead of the typical nasal passage thus encouraging particulate matter to become deposited on deeper and smaller passageways of the lungs, the areas associated with the greatest risk of transmission of infections[5]. A comprehensive study that considered the indoor air quality (IAQ) of gym environments observed individuals undertaking a high intensity `Body Attack' class breathed in more PM10 contaminants than those who engaged in a less intense yoga sessions for example. Those engaging in the former more intense exercise inhaled 40% more contaminants across men and 80% increase for women[6]. Even `moderate intensity' exercise encouraged particulate deposition within airways of up to 5X more particulate matter than someone present within the same setting but not exercising[7].

One study looked at the inhaled dose of pollutants during indoor physical activity within fitness centres. In this study, the inhaled dose is describedto be one of the key steps in the 'chain of events' resulting in the negative impacts on an individual's health following pollutant exposure. Thanks to the strong correlation between VE (minute ventilation- the quantity of air moved into and out of the lungs in a minute) and HR (heart rate), HR could be used as a viable proxy to determine inhaled doses of air pollutants as exercise was undertaken. The study explains `Once HR is mainly influenced by oxygen consumption and the correlation between oxygen consumption and VE is high, HR and VE are expected to be strongly associated', which is supported by other studies[8]. One study observed a sample all aged between 18-38 who were generally active, indicative of a young demographic of gym-goers[9]. This study continued by con rming our earlier reference to inhaled doses being higher in more intensive classes (a class characterised by fast vigorous movements and bodyweight exercises) than in less intense classes (`holistic' classes), in particular, PM10 inhaled doses were estimated to be more than four times greater in the more intense class. Thus, by assessing the inhaled dose of pollutants from the air within a gym setting, we identify a fundamental indicator of the harmful health impacts likely to be had by the athletes within. Additionally, the concept of `re-suspension' caused by the more vigorous intensive classes led to higher levels of airborne contamination by a factor of 1.4 due to the tendency of these types of activity to cause settled particles to again become airborne. This study concluded that the harmful impacts of low IAQ in a given fitness environment are more prevalent when strenuous exercise is undertaken because such activity increases concentrations of particulate matter, as well as increasing a given athletes susceptibility to inhaling these irritants.

### 03. Airborne contamination within a workout environment

Poor indoor air quality within the gym setting can also be considered a risk within the context of the ongoing COVID-19 pandemic, this is because poor IAQ is often associated with extremely poor air circulation, meaning the air in the room is circulated a very low number of times in a given hour. This can cause harmful virus contaminants released into the air to remain suspended for extended periods, before being potentially breathed in by unsuspecting individuals.

Within the context of the ongoing pandemic, caused by the SARS-CoV-2 virus, we can observe how minimal air changes can lead to airborne transmission of the virus between individuals[10] . When an individual in the gym, coughs, sneezes or even talks, both small `droplets' and even smaller 'aerosols' are released. In aerobiology, the larger of the two, namely `droplets' (>5 μm diameter), fall toward the ground on a rather steep trajectory (an arc shape) after leaving the individual, this means proximity is required for transmission person to person. However, the release of aerosols (<5 μm diameter) from an individual can travel much larger distances through the air and remain suspended within it for extended periods (if left untreated)- only to be breathed in by other individuals. The current coronavirus (only 0.12-0.16  m in diameter) is, therefore, able to remain airborne for extended periods as `aerosols'. Furthermore, the reproductive number (R0) of the SARS-CoV-2 virus is widely found to exceed that of the `SARS'[11] and `MERS'[12] outbreaks of 2002-2004 and 2012- respectively, indicating it is even more important to take measures to remove such virus aerosols from the air at the current time.

Furthermore, another research study found exposure to NO2 (a commonly found VOC in gyms) led to rhinitis and coughs in 18.3% and 18.7% of individuals respectively, which were subsequently attributed to an associated decline in athletic performance by gym-goers[13].  The rise in surface cleaning procedures within the gym environment, as a commonly undertaken measure to combat the ongoing pandemic is also likely to exacerbate poor IAQ. One study found the highest levels of CH2O (a particularly harmful VOC) concentrations to be found within a gym which used alcohol-based hand disinfectant throughout the gymnasium space, and recognised cleaning products as risks to respiratory health[14]. In another study the TVOC levels across university sports facilities and found concentrations of these contaminants to reach 2300 ppb (parts per billion) at times coincident with cleaning processes, whilst levels dropped to 30-40 ppb during night-time when cleaning procedures did not occur[15]. In particular, this study found disproportionally high levels of numerous carbonyl compounds (every type measured) in indoor university sports facilities vs. outdoor facilities. Acrolein' levels were notably high, a VOC known to exert toxic effects when either inhaled, ingested orally or dermatologically exposed, including harmful effects to the mucous membranes, and at high concentrations, irritation to the skin. A meta-analysis of related studies on physical exercise facility air quality) also found indoor facilities to be more polluted than outside ones across 75% of studies16. An explanation for this might be that many VOCs are emitted by consumer products as well as structures that are usually found in the indoor environments as opposed to outside ones, including carpeting, furniture cleaners, paints, perfumes, lacquers, and solvents17

It is clear therefore that athletes, as well as the average gym-goer, are similarly at risk when practicing exercise in a polluted environment[18] , and it is thus the case that studies have called for increased attention to be paid to the environments within which high-intensity exercise takes place[19]. Such a study makes speci  c reference to the need to address the types of ventilation available and the need for air recirculation within such a high-risk setting to reduce the risk of breathing particulate matter suspended within the air. There are calls for the need to optimise ventilation rates and occupant's behaviour to reduce air pollutant exposure within such high-risk environments[20]. Not only would such practices allow for a reduction in the potentially harmful impacts of low IAQ, but studies have also found a positive e  ect on the comfort of those exercising, caused by the movement of air in the environment, providing yet another reason for mechanical air change implementation[21].

Powerful mechanical re-circulation is capable of air throughput exceeding 600m$^3$, meaning in a gym of 100m$^3$, the achieved air exchange rate (AER) would reach 6 rotations/hour. This can be contrasted with the less than 3 air changes per hour (ACH) achieved in 75% of the gyms investigated in a European study in 2014[22].

This study also found that the only fitness centre that opened windows to ventilate the indoor fitness centre, had the highest level of airborne coarse particles contaminating the indoor air. This gym specifically was located in a city (known for their generally poor air quality), perhaps explaining the high level of contaminants within. The types of solutions capable of delivering improvements to IAQ need to have suitable air intake locations, as well as sufficient effciency of air filtration in order to achieve maintenance of a good IAQ[23].

## 04. IAQ and its impact on sleep

The Global Burden of Disease ranks air pollution as the 4th most prominent risk to health after high blood pressure, dietary risks and smoking[24]. We spent 90% of our time indoors and a large proportion of that is spent inside our bedrooms, measuring around 7-8 continuous hours a day[25]. These micro-environments favour low IAQ for a number of reasons, leading to the existence of numerous airborne contaminants within such environments. Firstly, numerous household products likely to lead to air contamination commonly exist within the bedroom, these include, air freshers, candles, deodorant, carpets, and many others [26]. Additionally, these areas of the home are likely to have their air contaminants diluted to a lesser extent than the rest of the home due to the intention of homeowners to lower the number of air changes in such rooms, in order to improve the energy efficiency of the home. Such intentions have an indirect relationship with the quality of air within the bedroom setting.

Furthermore, the radiators present in the bedroom provide favourable conditions for the creation of harmful semi-VOCs. It is further believed that those consider wealthier are generally exposed to increased indoor exposure, thanks to their tendency for more frequent house renovations/retrofitting, as well as the purchasing of carpets and use of luxury items such as candles, sprays as well as other household products and goods. Resultantly, much of the research suggests a need for species attention to resolve likely increased risk to those within such setting.

During sleep, individuals breathe passively and are, for prolonged periods, exposed to potentially thousands upon thousands of toxic chemicals suspended within their air[27]. It is particularly important to provide adequate air filtration within such a setting because not only is this prolonged exposure a risk, but IAQ cannot easily be perceived by humans.

We rely purely on the sensory effects these contaminants can have (eg. odours, eye irritation, breathing irritation etc or headaches) to gauge pollutants levels and therefore usually are unaware of their high concentrations within the bedroom. A study conducted of 50 adults observed a clear relationship between particulate matter (PM10) and AHI (Apnea-Hypopnea Index)[28], this was indicative of increasing occurrences of sleep apnoea during the sleeping process of those exposed to high levels of contaminants. Increasing levels of air pollution were also found to trigger non-specific inflammation in the respiratory tract. Poor air quality can have detrimental effects on sleep quality, making particular reference to the impaired breathing such air is likely to cause within the individual[29]. Sleep quality can also be disturbed by unpleasant scents within the room, as well as exposure to cooking fumes, which can easily find their way into the bedroom thanks to natural convection currents within the house environment through and under doorways.

Sleep is widely considered by athletes, coaches and trainers alike as an important part of post-exercise recovery and is believed to be crucial for ensuring optimal performance is made possible. Furthermore, sleep is not only essential for physical recovery but the mental recovery it aids is also crucial. As a result, sleep disturbances, made more likely to occur in the presence of high levels of air contaminants, can affect `neural plasticity' and learning capabilities of an individual. It is also common for athletes in particular to suffer from non-restorative sleep, whereby they attain the minimum required number of hours, but the quality of the sleep is inadequate. Another study found that psycho-socio-physiological stresses placed upon athletes within elite categories may inhibit abilities to get appropriate sleep, such a phenomenon is even more significant if the athlete is injured and in need of sleep to aid substantial physical recovery too. This study continues by explaining the necessity for athletes to constantly `strive to improve their sleep hygiene practises' as a way to constantly improve their overall elite performance[30] .

## 05. The importance of ensuring high IAQ for those who suffer from respiratory allergies

Furthermore, the research to suggest low air quality can cause exacerbations of respiratory allergies (i.e. asthma and rhinitis) is widely accepted throughout the scientific literature[31]. Studies show that even within the top three tiers of male professional football in the UK (English Football Premier League, Championship and League One), over a quarter of players (28%) were found to have exercise-induced bronchoconstriction, thus highlighting the prominence of such a condition even at the elite level. Such a study exposed 97 footballers to a eucapnic voluntary hyperpnoea (EVH) challenge to diagnose EIB (exercise-induced bronchoconstriction) and found that only 37% of those who tested positive for symptoms of the condition had highlighted a history of EIB/asthma[32]. This highlights the lack of awareness of such conditions and the need to provide conditions breathing and air quality favourable to those with such symptoms, even if they have not been offcially diagnosed.

## 06. Air Purification as the solution to poor IAQ

Air purification technology is widely considered able to play a key role in protecting human health by way of reducing the indoor air pollutants associated with the health concerns referred to thus far. This has led to the adoption of such units across numerous settings including both hospital and dental environments, and an ever-increasing adoption in commercial settings as the health benefts associated are realised further. Liu et al. 2020 however explains that purification methods or solutions need to account for the variety of potential air pollutants by combining various purifcation methods to ensure all types of pollutants present in the air are accounted for. This will help protect individuals against the potentially detrimental health risks associated with breathing in harmful particulate matter.

The table below outlines the different types of methods used to capture/ eliminate varying contaminants.

| | Dust, pollen, secondary pollutants, lampblack, etc<br>Diameter 0.01-100 pm | Formaidehyde, benzene, ammonia, etc<br>Diameter 0.0001-0.001 pm | Bacteria<br>Diameter 0.2-10 pm | Virus<br>Diameter 0.2-10 pm |
|---|---|---|---|---|
| Filtration | Effective | Noneffective | Effective | Noneffective |
| Adsorption | Partially effective | High-efficiency | Partially effective | Noneffective |
| Water washing Purification | Effective | Partially effective | Noneffective | Noneffective |
| Electrostatic Precipitation | Effective | Not obvious | Partially effective | Noneffective |
| Anion technology | Effective | Not obvious | Partially effective | Noneffective |
| Photocatalysis purifying technology | Not obvious | Effective | Effective | Effective |
| Plasma cleaning technology | Not obvious | Effective | Effective | Effective |
| Ultravioet radiation | Noneffective | Noneffective | High-efficiency | High-efficiency |

Source: Liu, G., Xiao, M., Zhang, X., Gal, C., Chen, X., Liu, L., Pan, S., Wu, J., Tang, L. and Clements-Croome, D., 2017. A review of air filtration technologies for sustainable and healthy building ventilation. Sustainable Cities and Society,[online] 32, pp.375-396[33].

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 air. 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- needs its filters constantly replaced, will be extremely noisy, and ultimately ineffective at purifying the air.

### 06.01. How well does an air purification unit purify the in-door air?

As previously outlined, the contaminants likely to be present in the indoor air of a gym or indoor facility are plentiful and potentially include numerous viruses, bacteria, fungi, as well as larger particulate matter impurities such as dust, pollen, and other irritants. As such, the removal of such pathogens requires a combination of filtration and elimination technolo-gies to operate synergisti-cally[34]. 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.

### 06.02. The necessary technologies within the air purification literature:

#### 06.02.01. Pre-filters

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

#### 06.02.02. Carbon filters

Carbon filters (or 'activated carbon') are an advanced type of filter that allows organic compounds to be removed from the air as well as odours and other potentially present gas pollutants[35].

#### 06.02.03. HEPA (High-Efficiency Particulate Air) filters

A HEPA filter is capable, by definition, of capturing at least 99.97% of partic-ulate 0.3 microns in diameter[36]). 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 partic-ulates within the unit[37]. 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[38]. 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[39].

#### 06.02.04. UV-C Irradiation

UV light refers to a very powerful light just outside the visible spectrum to hu-mans. 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 infrastruc-ture) meaning their use is safe to the user.

#### 06.02.05. Air ionisation

Air ionisation involves the application of high voltage to one (or more) needles, causing them to act as electrodes. This process encourages electrons within the internal circuit to move towards the needlepoint, which pushes the electrons towards one another. The negatively charged electrons repel each other and fall from the needle only to land on the nearest airborne particle- thus exerting their negative charge on said particle. This process occurs across lots of particles within the air, which soon repel one another due to their charge, and becoming attracted to the earth- only to be removed from the environment by regulatory surface cleaning procedures.

### 06.03. The importance of UV-C irradiation with an Air Purification unit

UV-C irradiation is widely considered an extremely effective method of air pu-rification. The high energy wavelengths emitted in this process (of between 200-280nm) are capable of damaging the DNA or RNA of microorganisms such as bacteria and viruses, deeming them no longer able to perform their vital functions. In the case of DNA, after exposure, the collision of photons in the cell causes their energy to become absorbed by the nucleic acids.

Following this, pyrimidine dimers lead to a change in the DNA structure, followed by mutation and ultimately the death of the cell. 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 bio-aerosols in US health centres[40].

The effectiveness of four different UV-C emitting purification units was tested individually for their ability to disinfect bio-aerosols of air-borne bacteria. The bioaerosols used for testing were vegetative cells of the following: Escherichia coli, Micrococcus luteus, Pseudomonas fluorescens, Staphylococcus aureus, and endospores of Bacillus Subtilis. Results showed all four units were able to kill in excess of 99% of all the airborne vegetative bacteria tested and over 75% for the B. Subtilis Endospores. This study concluded 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[41]. Despite the extensive research-based evidence validating this technol-ogy, many purification solutions do not utilise UV-C radiation. This omission is detrimental for a number of reasons.

To begin with, viruses are amongst the most harmful particulate matter encountered via airborne transmission. Many virus particulates measure sub-micron diameters- reaching the size of 0.12-0.16 diameter in the case of COVID-19 [42]. Because of this, a HEPA-filter (which by definition filters >99.97% of >0.3 microns) will not always be sufficient as a means of purification. This is because the efficacy of HEPA filters below this level is dependent on a less consistent particle-capturing mechanism, namely 'diffiusion' due to the 'Brow-nian dominant' motion of particles at this size[43]. UV-C, however, has proved effiective at deactivating such viruses from contaminated air at extremely high efficacy[44]. Furthermore, HEPA filters, despite their extremely high efficacy and aluable influence on the purifica-tion process[45], do not actively kill airborne particulate matter (such as viruses, bacteria, or fungi).

One study considered the possibility of previously captured aerosols re-entering the purified environment at a later stage if left untreated in the HEPA filter. The same study also considered that the build-up of bacteria on the HEPA filter over time could lead to the formation of a significant 'breeding ground' for pathogens[46]. The utili-sation of UV-C bulbs integrated into the design of purifiers, however, has the potential to eradicate such an issue by damaging the DNA and RNA structures of trapped pathogens, effectively killing them. Such a process is also likely to extend the life of a HEPA filter by preventing large build-ups, thus reducing maintenance costs to the operator. Resultantly, researchers such as[47], who also observed the ability of UV-C irradiation to remove bioaerosols at very high rates suggests the use of such technology within the hospital environment.

UV-C irradiation effectiveness is proportional to the wattage of the UV-C bulbs used in the purifier[48]. As such, not only is the presence of UV-C capability imperative, as well as the careful integration of these bulbs into the design engineering of a purifier but also important to consider is the strength of these bulbs (measured in wattage). Existing models on the market vary from a low of 10W up to an impressive 24W. Furthermore, dust agglomerations can impact the efficacy of the UV because such particulates impact the UV light's potential penetration49. Having considered the above insights, it may be beneficial to utilise a unit capable of relatively higher UV-C irradiation wattage.

### 06.04. 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. Many products claim to be able to purify the air within rooms up to a certain '$m^2$' size, however important to understand is the lack of a standard measure by which to verify or disprove this purification capacity claim. Such confusion leads to much hypocrisy in the market and a lack of clarity to the consumer. A far more transparent method of measuring the power of a unit is to understand what volume of air the unit is capable of processing in one hour and can be summarised by the following metric – 'meter3 throughput 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.

In the case of a bedroom, we might assume a very large bedroom to measure 5 meters wide, 7 meters long and have a ceiling height of 2.5 meters, that would give a total volume of 87.5$m^3$. We could then assume that a purifier that indicated a throughput capability of up to 600$m^3$ (in the case of the 'MedicAir' unit [50] ) could process or 'turn-over' the air in that room well over 6 times per hour. To put this into context, this would mean the purification unit delivered in excess of the air changes per hour indicated necessary within an NHS hospital ward[51]). In the context of a gym, we might expect a larger room, in which case multiple units may be required to operate in synergy with one another to provide the deserved improvements in air quality, for example, three units with the same 600$m^3$ capability would be able to turn over the air in a gym of 10mx10mx4m (400$m^3$) a total of 4.5 times per hour.

It is also important to consider air puri cation units that are powerful enough to ensure that they are 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 inexcess 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 infec-tion 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

## 07. Concluding remark

This white paper considered research specifically undertaken to evaluate the damaging role of low air quality with indoor environments, with specific at-tention devoted to the gym, as well as the bedroom setting. Such a field of study is of particular concern during the ongoing 'COVID-19' pandemic, how-ever, 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 'air purification', this paper takes a more in-depth look at the potential of air purification units to provide a healthier indoor environment. The technolo-gies 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 both settings considered as part of measures to ensure performance is optimised. It is essen-tial 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.

[1]Alves et al. 2013, [2]Alves et al. 2013, [3]Aguiar et al. 2014
[4]Andrade et al. 2018, [5]Harrel et al. 2004, [6]Ramos et al. 2015, [7]Daigle et al. 2003, [8]Zuurbier et al. 2009
[9]Ramos et al. 2015, [10]Ge, Z. et al. 2020, [11]Liu, Y. et al. 2020
[12]Al-Taw q, J. et al. 2014, [13]Andrade et al. 2014
[14]Ramos et al. 2014, [15]Alves et al. 2013, [16]Andrade et al. 2018, [17]Ramos et al. 2014, [18]Ramos et al. 2014, [19]Andrade et al. 2018, [20]Ramos et al. 2014, [21]Zhai et al. 2015, [22]Ramos et al. 2014, [23]Ramos et al. 201, [24]Katsoyiannis et al. 2019
[25]Strom-Tejsen et al. 2015
[26]Katsoyiannis et al. 2019, [27]Katsoyiannis et al. 2019
[28]Gulhan et al. 2019, [29]Caddick et al. 2019, [30]Bird. 2013
[31]Marino et al. 2015, [32]Jackson et al. 2018, [33]Liu et al. 2017,
[34]Wargocki et al. 2005, [35]Fiegel et al. 2006
[36]Zeng et al. 2004, [37]Sehulster et al. 2004
[38]Chuaybamroong et al. 2010, [39]Jeong et al. 2019
[40]Jafari et al. 2018, [41]Green et al. 2001, [42]Ward et al. 2020
[43]Perry et al. 2016, [44]Kim et al. 2018, [45]Yadav et al. 2015,
[46]Chuaybamroong et al. 2010, [47]Kujundzic et al. 2007
[48]Kujundzic et al. 2007, [49]Van Osdell et al. 2002
[50]MedicAir, 2020, [51]Public Health England 2020

## 08. References

Aguiar, L., Mendes, A., Pereira, C., Neves, P., Mendes, D. and Teixeira, J., 2014. Biological Air Contamination in Elderly Care Centers: Geria Project. Journal of Toxicology and Environmental Health, Part A, [online] 77(14-16), pp.944-958. Available at: https://ww-w.tandfonline.com/doi/pdf/10.1080/15287394.2014.911135?needAccess=true [Accessed 5 June 2020].

Al-Tawfiq, J., Zumla, A. and Memish, Z., 2014. Travel implications of emerging coronaviruses: SARS and MERS-CoV. Travel Medicine and Infectious Disease, [online] 12(5), pp.422-428. Available at: https://ww-w.sciencedirect.com/science/arti-cle/pii/S1477893914001240 [Accessed 25 April 2020].

Alves, C., Calvo, A., Castro, A., Fraile, R., Evtyugina, M. and Bate-Epey, E., 2013. Indoor Air Quality in Two University Sports Facilities. Aerosol and Air Quality Research, [online] 13(6), pp.1723-1730. Available at: https://aaqr. org/articles/aaqr-13-02-oa-0045.pdf [Accessed 7 June 2020].

Andrade, A. and Dominski, F., 2018. Indoor air quality of environments used for physical exercise and sports practice: Systematic review. Journal of Envi-ronmental Management, [online] 206, pp.577-586. Available at: https://www. sciencedi-rect.com/science/article/pii/S0301479717310769 [Accessed 8 June 2020].

Bird, S., 2013. Sleep, Recovery, and Athletic Performance. Strength and Conditioning Journal, [online] 35(5), pp.43-47. Available at: https://www. researchgate.net/publication/257298429_Sleep_Re-covery_and_Athletic_ Performance_A_Brief_Re-view_and_Recommendations [Accessed 1 June 2020].

Buonanno, G., Fuoco, F., Marini, S. and Stabile, L., 2012. Particle Resuspen-sion in School Gyms during Physical Activities. Aerosol and Air Quality Re-search, [online] 12(5), pp.803-813. Available at: https://e-prints.qut.edu. au/77155/ [Accessed 8 June 2020].

Caddick, Z., Gregory, K., Arsintescu, L. and Flynn-Ev-ans, E., 2018. A review of the environmental parameters necessary for an optimal sleep environment. Building and Environment, [online] 132, pp.11-20. Available at: https://www. sciencedirect.com/science/arti-cle/abs/pii/S0360132318300325#! [Accessed 4 June 2020].

Chuaybamroong, P., Chotigawin, R., Supothina, S., Sribenjalux, P., Larpkiat-taworn, S. and Wu, C., 2010. Efficacy of photocatalytic HEPA filter on microor-ganism removal. Indoor Air, [online] 20(3), pp.246-254. Available at: https://www.research-gate.net/publication/44697454_Effica-cy_of_photocatalytic_ HEPA_filter_on_microorgan-ism_removal [Accessed 25 April 2020].

Daigle, C., Chalupa, D., Gibb, F., Morrow, P., Oberd¨or-ster, G., Utell, M. and Frampton, M., 2003. Ultrafine Particle Deposition in Humans During Rest and Exercise. Inhalation Toxicology, [online] 15(6), pp.539-552. Avail-able at: https://www.tandfon-line.com/doi/abs/10.1080/08958370304468 [Accessed 5 June 2020].

Fiegel, J., Clarke, R. and Edwards, D., 2006. Airborne infectious disease and the suppression of pulmonary bioaerosols. Drug Discovery Today, [online] 11(1-2), pp.51-57. Available at: https://www.sciencedirect.com/science/article/pii/S1359644605036871 [Accessed 3 May 2020]

Ge, Z., Yang, L., Xia, J., Fu, X. and Zhang, Y., 2020. Possible aerosol trans-mission of COVID-19 and special precautions in dentistry. Journal of Zhejiang University-SCIENCE B, [online] Available at: https://link.springer.com/article/10.1631/jzus.B2010010 [Accessed 25 April 2020].
Green, C. and Scarpino, P., 2001. The use of ultraviolet germicidal irradiation (UVGI) in disinfection of airborne bacteria. Environmental Engineering and Policy, 3(1), pp.101- 107.

Yıldız G¨ulhan, P., G¨ule¸c Balbay, E., Elveri¸sli, M., Er¸celik, M. and Arbak, P., 2019. Do the levels of particulate matters less than 10m and seasons affect sleep?. The Aging Male, 23(1), pp.36-41

Harrel, S, K. and Molinari, J. 2004. Aerosols and splatter in dentistry: a brief review of the literature and infection control implications. The Journal of the American Dental Association, 135(4):429–437, 2004

Jafari, A, J., Rostami, R. and Ghainv, G. 2018. Advance in bioaerosol removal technologies; a review. Iranian journal of health science and environment, [on-line] 5(2). Available at: http://www.ijhse.ir/index.php/IJHSE/article/view/290 [Accessed 1 May 2020].

Jeong, S., Heo, K. and Lee, B., 2019. Antimicrobial Air Filters Using Natural Sea Salt Particles for Deactivat-ing Airborne Bacterial Particles. International Journal of Environmental Research and Public Health, 17(1), p.190.

Jackson, A., Hull, J., Hopker, J. and Dickinson, J., 2018. Impact of detect-ing and treating exercise-induced bronchoconstriction in elite footballers. ERJ Open Research, [online] 4(2), pp.00122-2017. Available at: https://www.ncbi. nlm.nih.gov/pmc/articles/PMC5909043/ [Accessed 3 June 2020].

Katsoyiannis, A. and Cincinelli, A., 2019. 'Cocktails and dreams': the indoor air quality that people are exposed to while sleeping. Current Opinion in En-vironmental Science Health, [online] 8, pp.6-9. Available at: https://www. sciencedirect.com/science/article/abs/pii/S2468584418300709#! [Accessed February 2020].

Kujundzic, E., Hernandez, M. and Miller, S., 2007. Ultraviolet germicidal ir-radiation inactivation of airborne fungal spores and bacteria in upper-room air and HVAC in-duct configurations. Journal of Environmental Engineering and Science, [online] 6(1), pp.1-9. Available at: https://www.nrcresearchpress.com/doi/abs/10.1139/s06-039#.XraxaxNKhQJ [Accessed 3 May 2020].

Kim, K., Kabir, E. and Kabir, S., 2015. A review on the human health impact of airborne particulate matter. Environment International, [online] 74, pp.136-143.

Kim, D. and Kang, D., 2018. UVC LED Irradiation Effectively Inactivates Aerosolized Viruses, Bacteria, and Fungi in a Chamber-Type Air Disinfection System. Applied and Environmental Microbiology, [online] 84(17). Available at: https://aem.asm.org/content/aem/84/17/e00944-18.full.pdf [Accessed 1 May 2020].

Liu, G., Xiao, M., Zhang, X., Gal, C., Chen, X., Liu, L., Pan, S., Wu, J., Tang, L. and Clements-Croome, D., 2017. A review of air filtration technologies for sustainable and healthy building ventilation. Sustainable Cities and Society, [online] 32, pp.375-396. Available at: https://www-sciencedirect-com. iclibezp1.cc.ic.ac.uk/science/article/pii/S221067071630734X#sec0155 [Accessed 3 June 2020].

Liu, Y., Gayle, A., Wilder-Smith, A. and Rockl¨ov, J., 2020. The reproductive number of COVID-19 is higher compared to SARS coronavirus. Journal of Travel Medicine, [online] 27(2). Available at: https://academic.oup.com/jtm/article/27/2/taaa021/5735319 [Accessed 26 April 2020].

Marino, E., Caruso, M., Campagna, D. and Polosa, R., 2015. Impact of air quality on lung health: myth or reality?. Therapeutic Advances in Chronic Disease, [online] 6(5), pp.286-298. Available at: https://journals.sagepub. com/doi/pdf/10.1177/2040622315587256 [Accessed 2 June 2020].

Perry, J, L., Agui, J, H. and Vijayakumar, R. 2016. Submicron and Nanopar-ticulate Matter Removal by HEPA-Rated Media Filters and Packed Beds of Granular Materials. National Aeronautics and Space Administration (NASA). [online]. Available at: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170005166.pdf [Accessed 2 May 2020].

Public Health England, 2020. COVID-19: Infection Prevention And Control Guidance. COVID-19. [online] Gov.uk. Available at: https://assets. publishing.service.gov.uk/government/uploads/system/uploads/attachment_ data/file/881489/COVID-19_Infection_prevention_and_control_guidance_complete.pdf [Accessed 27 April 2020].

Ramos, C., Reis, J., Almeida, T., Alves, F., Wolterbeek, H. and Almeida, S., 2015. Estimating the inhaled dose of pollutants during indoor physical activity. Science of The Total Environment, [online] 527-528, pp.111-118. Available at: https://www.sciencedirect.com/science/article/pii/S0048969715300541#bb0230 [Accessed 4 June 2020].

Ramos, C., Wolterbeek, H. and Almeida, S., 2014. Exposure to indoor air pollutants during physical activity in fitness centers. Building and Environ-ment, [online] 82, pp.349-360. Available at: https://www.sciencedirect. com/science/article/abs/pii/S0360132314002856 [Accessed 6 June 2020].

Sehulster LM, Chinn RYW, Arduino MJ, Carpenter J, Donlan R, Ashford D, Besser R, Fields B, McNeil MM, Whitney C, Wong S, Juranek D, Cleveland J. 2004. Guidelines for environmental infection control in health-care facilities. Recommendations from CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). Chicago IL; American Society for Healthcare Engineering/American Hospital Association.

Strøm-Tejsen, P., Zukowska, D., Wargocki, P. and Wyon, D., 2015. The ef-fects of bedroom air quality on sleep and next-day performance. Indoor Air, [online] 26(5), pp.679-686. Available at: https://onlinelibrary.wiley.com/doi/full/10.1111/ina.12254 [Accessed 13 June 2020].

Van Osdell D., Foarde K. (2002) DEFINING THE EFFECTIVENESS OF UV LAMPS INSTALLED IN CIRCULATING AIR DUCTWORK. AIR CONDI-TIONING AND REFRIGERATION TECHNOLOGY INSTITUTE 4100 N. Fairfax Drive, Suite 200, Arlington, Virginia 22203 Wang, Z. and Zhang, J., 2011. Characterization and performance evaluation of a full-scale activated carbon-based dynamic botanical air filtration system for improving indoor air quality. Building and Environment, 46(3), pp.758-768.

Ward, P., Higenottam, T., Gabbay, F., Holland, B. Tansey, S. and Saleem, T. 2020. COVID-19/SARS-CoV-1 Pandemic'. Faculty of pharmaceutical Medicine.

Wargocki, P., Wyon, D., Matysiak, B. and Irgens, S. (2005) The effects of classroom air temperature and outdoor air supply rate on performance of school work by children. In: Yanx, X., Zhao, B., Zhao, R. (eds) Proceedings of Indoor Air 2005, Vol. I(1), pp. 368–372, Beijing, Tsinghua University Press.

Yadav, N., Agrawal, B. and Maheshwari, C., 2015. Role of high-efficiency par-ticulate arrestor filters in control of air borne infections in dental clinics. SRM Journal of Research in Dental Sciences, [online] 6(4), p.240. Available at: http: //www.srmjrds.in/article.asp?issn=0976-433X;year=2015;volume=6;issue=4;spage=240;epage=242;aulast=Yadav#ref14 [Accessed 25 April 2020].

Yıldız G¨ulhan, P., G¨ule¸c Balbay, E., Elveri¸sli, M., Er¸celik, M. and Arbak, P., 2019. Do the levels of particulate matters less than 10m and seasons affect sleep?. The Aging Male, [online] 23(1), pp.36-41. Available at: https://www. tandfonline.com/doi/pdf/10.1080/13685538.2019.1655637?needAccess=true [Accessed 2 June 2020].

Zeng, H., Jin, F. And Guo, J. 2004. Removal of elemental mercury from coal combustion flue gas by chloride-impregnated activated carbon. [online]. 83(1).

Zhai, Y., Elsworth, C., Arens, E., Zhang, H., Zhang, Y. and Zhao, L., 2015. Using air movement for comfort during moderate exercise. Building and Envi-ron-ment, [online] 94, pp.344-352. Available at: https://www.sciencedirect. com/science/article/abs/pii/S0360132315301074 [Accessed 5 June 2020].

Zuurbier, M., Hoek, G., Hazel, P. and Brunekreef, B., 2009. Minute ventilation of cyclists, car and bus passengers: an experimental study. Environmental Health, [online] 8(1). Available at: https://link.springer.com/article/ 10.1186/1476-069X-8-48#auth-1 [Accessed 5 June 2020].