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Aéraulique et COVID-19

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Google Scholar, Lens et WoS

Mahmoudi, A., Tavakoly Sany, S. B., Ahari Salmasi, M., Bakhshi, A., Bustan, A., Heydari, S.*, et al.*
Application of nanotechnology in air purifiers as a viable approach to protect against Corona virus.
Iet Nanobiotechnology, Vol. **17** n°(4), (2023), 289-301 p.

The outbreak of COVID-19 disease, the cause of severe acute respiratory syndrome, is considered a worldwide public health concern. Although studies indicated that the virus could spread through respiratory particles or droplets in close contact, current research have revealed that the virus stays viable in aerosols for several hours. Numerous investigations have highlighted the protective role of air purifiers in the management of COVID-19 transmission, however, there are still some doubts regarding the efficiency and safety of these technologies. According to those observations, using a proper ventilation system can extensively decrease the spread of COVID-19. However, most of those strategies are currently in the experimental stages. This review aimed at summarising the safety and effectiveness of the recent approaches in this field including using nanofibres that prevent the spread of airborne viruses like SARS-CoV-2. Here, the efficacy of controlling COVID-19 by means of combining multiple strategies is comprehensively discussed.

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Kanda, K., Nishimura, H., Koiso, T., Takemoto, K., Nakagoe, K., Yamada, T.*, et al.*
Applying negative ions and an electric field to countermeasure droplets/aerosol transmission without hindering communication.
Scientific Reports, Vol. **13** n°(1), (2023)

In the COVID-19 pandemic, lockdown and acryl partitions were adopted as countermeasures against droplets/aerosol infections; however, these countermeasures restrict communication. In this study, a blocking device was developed using negative ions and an electric field. The device blocks mists simulating droplets/aerosol by a maximum of 89% but transmits light and sound, which is important for communication. The device demonstrated effective blocking performance for aerosol, including the COVID-19 virus spread from patients in a clinic. Our device can help prevent infections without disrupting communication.

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Sung, J. C.-C., Wu, P.-L., So, E. Y.-M., Wu, K.-C., Chan, S. M.-N., Kwong, K. W.-Y.*, et al.*
Assessment of novel antiviral filter using pseudo-type SARS-CoV-2 virus in fast air velocity vertical-type wind tunnel.
Scientific Reports, Vol. **13** n°(1), (2023)

Current evidence suggests that severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) can remain suspended spread in aerosols for longer period of time under poorly ventilated indoor setting. To minimize spreading, application of antiviral filter to capture infectious aerosols and to inactivate SARS-CoV-2 can be a promising solution. This study aimed to develop a method to assess simultaneously the filtration and removal efficiency of aerosolized pseudo-type SARS-CoV-2 using a vertical-type wind tunnel with relatively high face velocity (1.3 m/s). Comparing with the untreated spunlace non-woven filter, the C-POLAR™ treated filter increased the filtration efficiency from 74.2 ± 11.5% to 97.2 ± 1.7%, with the removal efficiency of 99.4 ± 0.051%. The results provided not only solid evidence to support the effectiveness of the cationic polymeric coated filter in fighting against the SARS-CoV-2 pandemic, but also a method to test viral filtration and removal efficiency under relative fast air velocity and with a safer environment to the operators.

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Walkinshaw, D. S., Horstman, R. H.
Covid 19 and beyond: a procedure for HVAC systems to address infectious aerosol illness transmission.
Frontiers in Built Environment, Vol. **9**, (2023)

From pandemic to seasonal, the COVID-19 pandemic experience suggests many common respiratory infections rather than likely having a fomite etiology as previously thought, are primarily caused by the inhalation of infectious aerosols shed by ill persons during coughing and normal breathing and talking. Given this new understanding, the good news is that, unlike indoor-sourced noxious and irritating gases that can only be mitigated practically by diluting them with outdoor air ventilation, the indoor infectious aerosol illness transmission route can be addressed by circulating already conditioned air through commonplace commercial filters. Given that infectious aerosols released from the breath of occupants were practically an unknown vector of respiratory disease in the healthcare community for many decades, understandably HVAC regulations have not addressed this issue yet. However, this is about to change. To further this new end, this paper develops the formulae needed to set conditioned air recirculation rates through such filters for design infectious aerosol emission and inhalation rates, HID values, exposure times and occupancies, and target significantly lower than currently normal airborne infection reproduction rates. The analysis extends the equations previously developed for group inhalation of infectious aerosols to develop equations predicting the number of infections likely to occur from this inhalation and the rate of disease spread (reproduction). The governing equations provided and exemplified use group exposures since the number of infections (reproduction number) is group based. Examples using the equations provided are given for many different settings and two case study findings are compared with their predictions. Some settings such as the typical office are shown to already have a relatively low infection reproduction rate. Alternatively, others such as a typical school classroom or a longer commercial air flight require increased filtered ventilation air flows to yield a similarly low reproduction rate. The formulae and their application will be of interest to government and industry health and HVAC standard setting bodies.

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Cao, R., Qiu, P., Xu, B., Lin, J., Chu, D., Fan, Z.
Effectiveness of interventions to reduce aerosol generation in dental environments: A systematic review.
Preventive Medicine Reports, Vol. **35**, (2023)

Certain dental procedures produce high levels of aerosols containing pathogenic microorganisms, posing a risk for the transmission of infections in dental settings. This study aimed to assess the effectiveness of various aerosol mitigation interventions during clinical dental procedures in real-world environments. A systematic literature search was conducted in PubMed/MEDLINE, Scopus, Web of Science, and Embase for English studies up to March 2023 according to the PRISMA guidelines. Only peer-reviewed controlled clinical trials (CCT) or randomized controlled trials (RCT) studies involving human subjects were included. The risk of bias of selected researches were evaluated by two independent authors using the Cochrane Collaboration tool. The literature search yielded 3491 articles, of which 42 studies met the inclusion criteria and were included in this study. Most studies evaluated bacterial contamination in bio-aerosols, while the viral and fungal contamination was assessed in only three studies. Overall, various approaches have been applied in reducing aerosol contamination in clinical scenarios, including high-volume evacuators (HVE), mouse rinses and rubber dams, air cleaning systems, and high-efficiency particulate air (HEPA) filters. The available evidence suggests that various aerosol mitigation strategies could be implemented to decrease the risk of cross-infection during clinical dental procedures in real-world environments. However, further clinical trials are necessary to establish statistical validity in measuring aerosol contamination and mitigation, as well as to evaluate the risk of infection transmission for viral and fungal contamination.

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Shin, H. W., Kang, D. H.
Estimation of airborne infection risk in a school classroom according to operation of a floor-standing type ventilation system.
Journal of Building Engineering, Vol. **78**, (2023)

Horizontal airflow, typically from floor-standing type ventilation systems used in school classrooms in some countries including Korea, may increase the risk of airborne infection. To estimate such risk, we conducted experiments in a classroom using simulated particles (DEHS) following the ventilation system discharge angles [upward (+45°), straight (0°), and downward (−45°)] and airflow rate (200 and 400 m3/h), along with desk partitions and simulated human heat release in a classroom. Calculations using the revised Wells–Riley equation showed that horizontal air supply potentially increases the infection risk by transporting particles [coarse (3.0–5.0 μm) and fine (0.5–3.0 μm)] over extended distances, from the air inlet to the back of the classroom. In comparison, downward air supply reduced the overall average infection risk by 30.1% compared with horizontal direction. Desk partitions yielded inconsistent effects, with short-term (5 min) and long-term (20 min) reductions in infection risk. However, when the internal heat gain increased, the average estimated infection risk decreased by 24.0%. Therefore, the risk of airborne infection could be reduced by changing the discharge angle of ventilation systems. Our findings could be useful in developing operating guidelines for existing ventilation systems or designing ventilation systems that reduce infection risk in classrooms.

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Sabancı, V., Güngör, S.
Experimental Investigation on the Thermal Performance of an Office-Type Heat Recovery Ventilation System.
7th International Students Science Congress. 12-13 may 2023, Izmir, Türkiye

Considering the global energy crises and climate change, the importance of energy recovery grows day by day. At this point, heat recovery ventilation (HRV) systems contribute energy saving by the help of heat exchange in between the cold and hot air streams. Furthermore, the Covid-19 pandemic shows us that ventilation is an inevitable part of heating, ventilation, air-conditioning and refrigeration (HVAC- R) systems to satisfy indoor air quality within the subregions of human-living constructions. In this experimental work, we use an industrial HRV system to examine the thermal performance under various air flow rates. The HRV unit mainly contains cold and hot stream fans, crossflow heat exchanger, air filter, and flow rate controller. The thermal scenarios are considered under winter climate conditions; therefore, temperature levels of the fresh and exhaust air streams are determined about 280K and 300K, respectively. In addition, thermal investigations are conducted with different mass flow rates. The temperatures are measured via thermocouples and collected by a precise multi-channel data logger. The results indicate that the investigated HRV system contribute both indoor air quality (complies with ASHRAE 62.1 standard) and reduction of air conditioning energy consumption.

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Chair, S. Y., Ng, S. T., Chao, C. Y. H., Xu, J. F.
Heating, ventilation, and air-conditioning systems in healthcare: A scoping review.
Journal of Hospital Infection, (2023)

Background
Guidelines for heating, ventilation, and air-conditioning systems have been developed for different settings. However, there is a lack of up-to-date evidence providing concrete recommendations for the heating, ventilation, and air-conditioning systems of an isolation room, which is essential to appropriately guide infection control policies. This scoping review aimed to highlight the guidelines for heating, ventilation, and air-conditioning systems in isolation rooms to inform relevant stakeholders and policymakers.
Methods

A systematic search was performed based on Joanna Briggs Methodology using five databases (CINAHL, EMBASE, Joanna Briggs Institute, Medline, and Web of Science) and websites. Eight articles published by government departments were included in this review. Results: Most studies recommended controlled airflow without recirculation, 12 air change per hour, high-efficiency particulate air filtrate to exhaust contaminated air from the airborne isolation room, ≤humidity 60%, and a temperatures in the range of 18–30 °C. Conclusions
This review highlights heating, ventilation, and air-conditioning systems guideline consistency across countries. This provides further evidence that there is a need for interdisciplinary collaborative research to quantify the optimum range for heating, ventilation, and air conditioning system parameters, considering door types, anterooms, and bed management, to effectively reduce the transmission of infection in isolation rooms.

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Fuster-Parra, P., Huguet-Torres, A., Castro-Sánchez, E., Bennasar-Veny, M., Yañez, A. M.
Identifying the interplay between protective measures and settings on the SARS-CoV-2 transmission using a Bayesian network.
Research Square, (2023)

During the COVID-19 pandemic, primary healthcare nurses played a crucial role in contact tracing to minimize the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) spread. However, contact tracing data were underutilized to explore the potential ways of virus transmission. Research on community spread, the effectiveness of individual protective measures, and the impact of different exposure environments is limited. This study focused on the transmission of SARS-CoV-2, aiming to describe the interplay between prevention measures and characteristics of exposure settings, using the data collated from a national SARS-COV-2 contact tracing programme to build a Bayesian network (BN) with 11 relevant features, which could potentially determine features with the strongest influence in SARS-CoV-2 transmission. BNs allow predictions of new scenarios when hypothetical information is introduced, which makes them of special interest in epidemiological studies. In our results, ventilation of the setting and time of exposure were the main factors for SARS-CoV-2 transmission. BN analysis can help decision-makers refine public health campaigns and priorise resources for individuals at higher risk, and also provides personalized guidance in specific protective measures for different settings or environments.

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Madhusudanan, A., Iddon, C., Cevik, M., Naismith, J. H., Fitzgerald, S.
Non-pharmaceutical interventions for COVID-19: a systematic review on environmental control measures.
Philosophical Transactions of the Royal Society A, Vol. **381** n°(2257), (2023)

The purpose of this review was to identify the effectiveness of environmental control (EC) non-pharmaceutical interventions (NPIs) in reducing transmission of SARS-CoV-2 through conducting a systematic review. EC NPIs considered in this review are room ventilation, air filtration/cleaning, room occupancy, surface disinfection, barrier devices, CO2 monitoring and one-way-systems. Systematic searches of databases from Web of Science, Medline, EMBASE, preprint servers MedRxiv and BioRxiv were conducted in order to identify studies reported between 1 January 2020 and 1 December 2022. All articles reporting on the effectiveness of ventilation, air filtration/cleaning, room occupancy, surface disinfection, barrier devices, CO2 monitoring and one-way systems in reducing transmission of SARS-CoV-2 were retrieved and screened. In total, 13 971 articles were identified for screening. The initial title and abstract screening identified 1328 articles for full text review. Overall, 19 references provided evidence for the effectiveness of NPIs: 12 reported on ventilation, 4 on air cleaning devices, 5 on surface disinfection, 6 on room occupancy and 1 on screens/barriers. No studies were found that considered the effectiveness of CO2 monitoring or the implementation of one-way systems. Many of these studies were assessed to have critical risk of bias in at least one domain, largely due to

confounding factors that could have affected the measured outcomes. As a result, there is low confidence in the findings. Evidence suggests that EC NPIs of ventilation, air cleaning devices and reduction in room-occupancy may have a role in reducing transmission in certain settings. However, the evidence was usually of low or very low quality and certainty, and hence the level of confidence ascribed to this conclusion is low. Based on the evidence found, it was not possible to draw any specific conclusions regarding the effectiveness of surface disinfection and the use of barrier devices. From these results, we further conclude that community agreed standards for well-designed epidemiological studies with low risk of bias are needed. Implementation of such standards would enable more confident assessment in the future of the effectiveness of EC NPIs in reducing transmission of SARS-CoV-2 and other pathogens in real-world settings.

This article is part of the theme issue 'The effectiveness of non-pharmaceutical interventions on the COVID-19 pandemic: the evidence'.

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Madhusudanan, A., Iddon, C., Cevik, M., Naismith, J. H., Fitzgerald, S.
Non-pharmaceutical interventions for COVID-19: a systematic review on environmental control measures. Supplementary material.
Philosophical Transactions of the Royal Society A, Vol. **381** n°(2257), (2023)

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Zhang, X., Liu, J., Liu, C.
A novel slip-velocity model to simulate the filtration performance of nanofiber media.
Process safety and environmental protection : transactions of the Institution of Chemical Engineers, Part B, Vol. **174**, (2023), 548-560 p.

Aerosols such as PM2.5 and PM10 can have an immense impact on human health. With the outbreak of SARS-CoV-2, it is urgent to filter aerosols by media filtration technology. Electrospun nanofibers are a promising material for achieving high efficiency, low resistance, light weight, and environmentally friendly air filtration. But research on filtration theory and computer simulation of nanofiber media is still lacking. The traditional method involving computational fluid dynamics (CFD) and Maxwell's first-order slip boundary overestimates the slip velocity on the fiber surface. In this study, a new modified slip boundary was proposed, which introduced a slip velocity coefficient on the basis of the no-slip boundary to address the slip wall. Our simulation results were compared with the experimental pressure drop and particle capture efficiency of real polyacrylonitrile (PAN) nanofiber media. The computational accuracy on pressure drop of the modified slip boundary improved 24.6% and 11.2% compared with that of the no-slip boundary and Maxwell's first-order slip boundary, respectively. It was found that the particle capture efficiency near the most-penetrating particle size (MPPS) was significantly increased when slip effect occurred. This may be explained by the slip velocity on the fiber surface, which would make particles more accessible to the fiber surface and captured by interception.

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Lavor, V., Coceal, O., Grimmond, S., Hang, J., Luo, Z.
Possible high COVID-19 airborne infection risk in deep and poorly ventilated 2D street canyons.
Building Simulation, (2023)

Despite the widespread assumption that outdoor environments provide sufficient ventilation and dilution capacity to mitigate the risk of COVID-19 infection, there is little understanding of airborne infection risk in outdoor urban areas with poor ventilation. To address this gap, we propose a modified Wells-Riley model based on the purging flow rate (Q(PFR)), by using computational fluid dynamics (CFD) simulations. The model

quantifies the outdoor risk in 2D street canyons with different approaching wind speeds, urban heating patterns and aspect ratios (building height to street width). We show that urban morphology plays a critical role in controlling airborne infectious disease transmission in outdoor environments, especially under calm winds; with deep street canyons (aspect ratio > 3) having a similar infection risk as typical indoor environments. While ground and leeward wall heating could reduce the risk, windward heating (e.g., windward wall similar to 10 K warmer than the ambient air) can increase the infection risk by up to 75%. Our research highlights the importance of considering outdoor infection risk and the critical role of urban morphology in mitigating airborne infection risk. By identifying and addressing these risks, we can inform measures that may enhance public health and safety, particularly in densely populated urban environments.

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Rocha-Melogno, L., Crank, K., Bergin, M. H., Gray, G. C., Bibby, K., Deshusses, M. A.
Quantitative risk assessment of COVID-19 aerosol transmission indoors: a mechanistic stochastic web application.
Environmental Technology, Vol. **44** n°(9), (2023), 1201-1212 p.

An increasing body of literature suggests that aerosol inhalation plays a primary role in COVID-19 transmission, particularly in indoor settings. Mechanistic stochastic models can help public health professionals, engineers, and space planners understand the risk of aerosol transmission of COVID-19 to mitigate it. We developed such model and a user-friendly web application to meet the need of accessible risk assessment tools during the COVID-19 pandemic. We built our model based on the Wells-Riley model of respiratory disease transmission, using quanta emission rates obtained from COVID-19 outbreak investigations. In this report, three modelled scenarios were evaluated and compared to epidemiological studies looking at similar settings: classrooms, weddings, and heavy exercise sessions. We found that the risk of long-range aerosol transmission increased 309-332% when people were not wearing masks, and 424-488% when the room was poorly ventilated in addition to no masks being worn across the scenarios. Also, the risk of transmission could be reduced by similar to 40-60% with ventilation rates of 5 ACH for 1-4 h exposure events, and similar to 70% with ventilation rates of 10 ACH for 4 h exposure events. Relative humidity reduced the risk of infection (inducing viral inactivation) by a maximum of similar to 40% in a 4 h exposure event at 70% RH compared to a dryer indoor environment with 25% RH. Our web application has been used by more than 1000 people in 52 countries as of September 1st, 2021. Future work is needed to obtain SARS-CoV-2 dose-response functions for more accurate risk estimates.

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Gaillard, A., Lohse, D., Bonn, D., Yigit, F.
Reconciling Airborne Disease Transmission Concerns with Energy Saving Requirements: The Potential of UV-C Pathogen Deactivation and Air Distribution Optimization.
Indoor Air, Vol. **2023**, (2023)

The COVID-19 pandemic caused a paradigm shift in our way of using heating, ventilation, and air-conditioning (HVAC) systems in buildings. In the early stages of the pandemic, it was indeed advised to reduce the reuse and thus the recirculation of indoor air to minimize the risk of contamination through inhalation of virus-laden aerosol particles emitted by humans when coughing, sneezing, speaking, or breathing. However, such recommendations are not compatible with energy saving requirements stemming from climate change and energy price increase concerns, especially in winter and summer when the fraction of outdoor air supplied to the building needs to be significantly heated or cooled down. In this experimental study, we aim at providing low-cost and low-energy solutions to modify the ventilation strategies currently used in many buildings to reduce the risk of respiratory disease transmission. Measurements of the indoor air bacterial concentration in a typical office building reveal that ultraviolet germicidal irradiation (UVGI) modules added to the HVAC system are very efficient at inactivating pathogens present in aerosols, leading to indoor concentrations as

low as outdoor concentrations, even with significant indoor air recirculation. Moreover, measurements of the CO₂ and aerosol air concentration reveal that, with air supply vents placed in the ceiling, placing the air exhaust vents near the floor instead of on the ceiling can improve the ventilation capacity in terms of effective flow rate, with significant consequences in terms of energy savings.

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Liu, H., Liu, Z., He, J., Hu, C., Rong, R., Han, H.*, et al.*
Reducing airborne transmission of SARS-CoV-2 by an upper-room ultraviolet germicidal irradiation system in a hospital isolation environment.
Environmental Research, Vol. **237**, (2023)

Upper-room ultraviolet germicidal irradiation (UVGI) technology can potentially inhibit the transmission of airborne disease pathogens. There is a lack of quantitative evaluation of the performance of the upper-room UVGI for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) airborne transmission under the combined effects of ventilation and UV irradiation. Therefore, this study aimed to explore the performance of the upper-room UVGI system for reducing SARS-CoV-2 virus transmission in a hospital isolation environment. Computational fluid dynamics and virological data on SARS-CoV-2 were integrated to obtain virus aerosol exposure in the hospital isolation environment containing buffer rooms, wards and bathrooms. The UV inactivation model was applied to investigate the effects of ventilation rate, irradiation flux and irradiation height on the upper-room UVGI performance. The results showed that increasing ventilation rate from 8 to 16 air changes per hour (ACH) without UVGI obtained 54.32% and 45.63% virus reduction in the wards and bathrooms, respectively. However, the upper-room UVGI could achieve 90.43% and 99.09% virus disinfection, respectively, with the ventilation rate of 8 ACH and the irradiation flux of 10 μW cm−2. Higher percentage of virus could be inactivated by the upper-room UVGI at a lower ventilation rate; the rate of improvement of UVGI elimination effect slowed down with the increase of irradiation flux. Increase irradiation height at lower ventilation rate was more effective in improving the UVGI performance than the increase in irradiation flux at smaller irradiation height. These results could provide theoretical support for the practical application of UVGI in hospital isolation environments.

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Lee, J. Y., Aghamohammadi, N.
Restaurant managers knowledge and intention to improve building ventilation and indoor air quality using control measures in a middle-income country.
Building and Environment, Vol. **244**, (2023)

Transmission of SARS-CoV-2 virus can occur via aerosol in inadequately ventilated indoor spaces, including restaurants. Despite the introduction of guidelines to ensure good indoor air quality (IAQ) and ventilation, business owners in low- or middle-income countries (LMIC) remain unsure about the regulations. This study aims to evaluate the level of knowledge and intention to improve IAQ and building ventilation among restaurant managers, and whether it is reflective of the implementation of control measures during COVID-19. This cross-sectional study involved restaurants from eight study sites at Kuala Lumpur, Malaysia, selected using cluster randomised sampling. A survey was conducted using a questionnaire adapted from the guidance note on ventilation and IAQ for non-residential setting during the COVID-19 pandemic by the Department of Occupational Safety and Health, Malaysia. Data collected were analysed using Statistical Package for the Social Sciences, version 27. Low knowledge level (median score: 4, range: 1–7) and moderate intention level (median score: 6, range 2–8) were reported among restaurant managers; however, the level of knowledge and intention were not correlated with the implementation of control measures. Insights from this study will be useful in informing the authorities to assess and review the practicality of current standard operating procedures and guidelines. The study findings are also expected to be translated to other airborne infectious diseases to increase the country's preparedness in managing future pandemics.

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Singgam, S., Lisam, B., Yurembam, S.

A review on management of droplet infection and aerosol in dental practice among practitioners during covid 19.

Journal of Advanced Medical and Dental Sciences Research, Vol. **11** n°(8), (2023), 91-98 p.

The transmission of infectious disease is very common among dental practioners as there is frequent direct contact with patients. It has become a life threatening area during the covid 19 pandemic. The aim of our study is to review/refurnished or brief on knowledge among dental practioners about the spread of infectious disease and droplet infection during dental practice so as to alert ways of management to prevent from further spread of infections. Method: Data were collected through pubmed and google scholar where previous published articles based on infectious disease and its control were mentioned using MESH terms. Result: Till the date 24 articles were found, out of which 7 satisfied our inclusion criteria.The following articles were analysed and Data were collected from the month of April 2020 till September 2020. Most of the studies reported that mode of transmission is frequent through direct contact /fomites and aerosols as stated by previous authors. Conclusion: The management of such situation is by adhering to strict protocols as mentioned in CDC guidelines and imparting further knowledge among practitioners about several infectious diseases and remaining updated as situation arises.

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Mohammadi, H., Akbari, H., Adibzadeh, A., Koozekonan, A. G., Akbari, H.

Ventilation system performance and its influence on indoor bioaerosols and thermal comfort in a COVID-19-designated hospital, Tehran.

Journal of Housing and the Built Environment, (2023)

This cross-sectional experimental study was conducted in 24 active coronavirus wards in an advanced hospital in Tehran. The performance of the ventilation system was initially evaluated according to ASHRAE 62.1, while thermal comfort was measured based on the Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) using the Center for the Built Environment tool and ASHRAE 55. The airborne concentrations of bacteria, viruses, and fungi were evaluated according to NIOSH 0800, and the concentration of the SARS-CoV-2 virus was also assessed. The relationship between ventilation parameters, indoor bioaerosols, and thermal comfort was also examined. Results showed a strong relationship between ventilation parameters, bioaerosol concentration, and thermal comfort. Increasing the ventilation rate led to a reduced concentration of bioaerosols and lower thermal comfort. The relationship between air temperature and bacterial and viral concentration was statistically significant. The outflow rate was directly related to the concentration of bacteria, fungi, and viruses but had a reverse relationship with PPD, PMV, and standard effective temperature. The relationship between the outflow rate and viral concentration was statistically significant. Considering the sensitivity of different groups within healthcare facilities, properly designing the ventilation system can result in thermal comfort, high indoor air quality, reduced infection risk, and improved patient health.

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