Strategies for Circulating Air Inside educational buildings to prevent the spread of the Coronavirus

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Abstract:

This research is basically focusing on studying the physical effects of the spread of Coronavirus within interior architectural spaces. In most international research centres concerning coping Covid-19 virus, similar studies were conducted to introduce ways of combating the spread of this virus. Places of human gatherings are more appropriate to carry out such studies related to finding ways to prevent the spread of Coronavirus infection. Therefore, educational buildings, especially classrooms and lectures halls are among the most crowded places, and their indoor space is ideal to a large extent for increasing the spread of Corona virus infection among people. The aim of this research is to calculate the rate of air change per hour in the interior spaces of educational buildings, based on the decision of the strategy of moving the air necessary to renew it by replacing clean air instead of polluted air by expelling it outside the building through a series of similar studies and applying to one of the educational halls. In this context, the methods of combating and preventing the Coronavirus were reviewed and the case of one of the halls was studied within one of the educational institutes in Dakahlia governorate and some recommendations were given that can be applied in similar institutes.

There are significant risks in building ventilation management and in maintaining healthy indoor environments. Dealing with the global epidemic of the covid-19 varies from one country to another, according to preventive measures, method, behaviour, and culture. The disease in Egypt becomes more brutal in the winter months at a time when people especially during work hours where the indoor atmosphere is closed and with poor ventilation conditions. Moreover, the Egyptian government tries to preserve its economy which is depending on different shapes of social interactions, such as commercial centres, public and private clubs, schools, universities, and government service organizations. In this context, the Egyptian government has eased the lock down restrictions gradually, and then cancelled it completely regarding certain vital associations such as universities, schools, commercial centres, and public services (UK-Government, 2018). Therefore, besides the national vaccination program for Egyptian citizens, it is also necessary to adopt the measures of the World Health Organization to prevent the spread of Covid 19 infection, including physical distancing, personal hygiene, and good ventilation of spaces, to obtain more effective results in limiting the spread of infection (World-Health-Organization, 2022).

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Keyword:
Circulating Air; Educational Buildings; Coronavirus Pandemic

الملخص:
هناك مخاطر كبيرة في إدارة تهوية المباني والحفاظ على بيئات داخلية صحية. يختلف التعامل مع الوباء العالمي لـ covid-19 من دولة إلى أخرى ، وفقًا للإجراءات الوقائية والأسلوب والسلوك والثقافة. يصبح المرض في مصر أكثر وحشية في أشهر الشتاء في وقت يكون فيه الناس في أثناء ساعات العمل بشكل خاص حيث يكون الجو الداخلي مغلقًا وظروف التهوية سيئة. علاوة على ذلك، تحاول الحكومة المصرية ساعية الحفاظ على اقتصادها الذي يعتمد على أشكال مختلفة من التجمعات والتفاعلات الاجتماعية، مثل المراكز التجارية والنوادي العامة والخاصة والمدارس والجامعات والمؤسسات الخدمية الحكومية. في هذا السياق ، قامت الحكومة المصرية بتخفيف قيود الإغلاق تدريجياً، ثم ألغتها نهائياً فيما يتعلق ببعض الجمعيات الحيوية مثل الجامعات والمدارس والمراكز التجارية والخدمات العامة. لذلك، فانه بجانب برنامج التطعيم الوطني للمواطنين المصريين، كان من الضروري أيضًا اتخاذ عدد من التدابير اللازمة والاجراءات المتبعة من منظمة الصحة العالمية لمنع انتشار عدوى كوفيد ٩ ، بما في ذلك التباعد الجسدي، وارتداء الكماما، والنظافة الشخصية، والتهوية الجيدة للمساحات ، للحصول على المزيد من الفعالية. حيث يؤدي ذلك بالتأكيد إلى الحد من انتشار العدوى.
في هذا السياق فان البحث يركز بشكل أساسي على دراسة الآثار المترتبة على انتشار فيروس كورونا داخل المساحات المعمارية الداخلية. في معظم مراكز الأبحاث الدولية المتعلقة بالتعامل مع فيروس Covid-19 ، أجريت دراسات مماثلة لإدخال طرق لمكافحة انتشار هذا الفيروس. أما أماكن التجمعات البشرية فهي أنسب لإجراء مثل هذه الدراسات المتعلقة بإيجاد طرق للوقاية من انتشار عدوى فيروس كورونا. كذلك تعتبر المباني التعليمية وخاصة الفصول الدراسية وقاعات المحاضرات الكبرى من أكثر الأماكن ازدحاما، كما أن مساحتها الداخلية مثالية إلى حد كبير لزيادة انتشار عدوى فيروس كورونا بين الناس. ان الهدف الرئيسي من هذا البحث هو حساب معدل تغير الهواء بالساعة في الفراغات الداخلية للمباني التعليمية، بناءً على الاستراتيجيات المناسبة لتحريك الهواء اللازم لتجديده باستبدال الهواء النظيف بدلاً من الهواء الملوث بطرده للخارج. من خلال سلسلة من الدراسات المماثلة وتطبيقها على إحدى القاعات التعليمية الموجودة بالفعل في أحد المباني التعليمية الشهيرة بمدينة طلخا بمحافظة الدقهلية، وفي هذا السياق تم استعراض طرق مكافحة فيروس كورونا والوقاية منه ودراسة الحالة المشار اليها وإصدار بعض التوصيات التي يمكن تطبيقها في المعاهد المماثلة.

الكلمات الدالة:
تحريك وتدوير الهواء، المباني التعليمية، جائحة كورونا

1. Introduction

There are significant risks in building ventilation management and in maintaining healthy indoor environments. Dealing with the global epidemic of the covid-19 varies from one country to another, according to preventive measures, method, behavior, and culture. The disease in Egypt becomes more brutal in the winter months at a time when people especially during work hours, where the indoor atmosphere is closed and with poor ventilation conditions. Moreover, the Egyptian government tries to preserve its economy which is depending on different shapes of social interactions, such as commercial centers, public and private clubs, schools, universities, and government service organizations. In this context, the Egyptian government has eased the lock down restrictions gradually, and then canceled it completely regarding certain vital associations such as universities, schools, commercial centers, and public services (UK-Government, 2018). Therefore, besides the national vaccination program for Egyptian citizens, it is also necessary to adopt the measures of the World Health Organization to prevent the spread of Covid 19 infection, including physical distancing, personal hygiene, and good ventilation of spaces, to obtain more effective results in limiting the spread of infection (World-Health-Organization, 2022).

2. Research Background

Coronavirus can spread through three main ways, droplets, direct contact, and in-flight. Mitigation strategies are discussed for dealing with these three spread ways, appropriate physical distancing and wearing of face masks proved to be effective ways helping to mitigate the viral particles transmissions. Regular hand washing and surface disinfection is also an effective way to prevent the spread of infection. The places where people gather is one of the places where the spread of the Coronavirus increases, such as clubs, gyms, public parks, administrative offices, classrooms in schools and educational halls in universities. These places are expected to make the airborne spread of the virus at the highest level (UK-Government, 2018; World-Health-Organization, 2022). Therefore, the primary concern of covid-19-architecture-research is the air/aerosol pathway and how to deal with this problem in spaces in which many people gather, especially university educational spaces, in terms of preventing the spread of infection with the Coronavirus, from an architectural point of view. Whereas natural ventilation strategies can be employed within the spaces of buildings to stop the spread of the virus through the three previously mentioned methods, as the natural identity helps reduce the concentration of virus particles in the indoor air of those spaces, and thus significantly reduce the chances of infection (UK-Government, 2018).

The assessment of Ventilation and monitoring of CO2 levels can indicate ventilation plans that can help managing the risk of Coronavirus infection through air. The concerning tests suggest that the more outside fresh air entering the interior space, the more adequate atmosphere for helping in minimizing the levels of reproduction numbers of viral particles inside. In cases of that the outdoor air supply is not integrated with the architectural design of buildings – this problem is often repeated in the Egyptian architecture – the risk of Coronavirus transmission by the airborne route increases, therefore, the recent architectural design should adopt the strategies that depend on natural ventilation with fresh-outdoor-air and circulating it inside the architectural spaces. In this context, the role is that the rate of provision of outdoor air can be inferred by monitoring CO2 levels in occupied spaces, maintaining these below about 1000ppm being indicative of adequate ventilation in many interior environments, including offices – with design guidelines for some interior spaces allow 1500 ppm (UK-Government, 2018). Where activity levels rise above desk-based work, however, higher ventilation rates may be required. Risks can also be reduced by reducing occupancy – while ensuring full outdoor air supply rates are maintained, Back occupancy – via appropriate oral, and the purge of internal spaces between events. This assessment is based on data derived from the SARS-COV-2 virus two strains that were prevalent during 2020. However, since the virus continues to change again, more transmissible, the variants are increasingly widespread. As these new strains are becoming dominant, current efforts to suppress the spread of Coronavirus may need to be revisited. Many additional design strategies are available to help further in reducing the risk of transmission and they are reviewed in detail (Mingotti, et al., 2020).

3. Research Objectives

The main objective of the research is to formulate a model for improving air movement strategies within educational spaces in a way that helps purify the indoor air as possible from any particles or droplets related to the Covid-19 virus. The model is mainly based on ASHREA standards to ventilate interior spaces to prevent the spread of Covid-19 virus, also to lead studies in the field of preventing the spread of Covid-19 inside educational spaces, which are conducted by Rhode Island Department of Health in the United States and the Centers for Disease Control and Prevention in the United Kingdom. The model is formulated by the researchers to take into account the circumstances and the special characteristics related to educational spaces existing in Egypt. The applied the model to a realistic case study, which is the main lectures hall at one of the educational institutions located in the city of Talkha, Dakahlia Governorate, which will be reviewed in detail in section 9. Thus, the rate of air change per hour in the interior spaces of educational buildings is studied and analyzed but not only for the improvement of indoor air quality but also for the prevention of the spread of Covid-19. The research intends to add an adapted strategy of moving the air necessary to renew indoor educational buildings spaces by replacing clean air instead of polluted air through expelling it outside the building. The model is intended to be applied in similar educational buildings in Egypt to become a pioneer in preventing the spread of Covid-19 virus in educational spaces.

4. The indoor spread of Coronavirus

Domestic spread of Coronavirus, Florence Nightingale is often credited with promoting the idea of the indoor environment plays a critical role in determining health outcomes. Her leading work on hospital ward design is still applicable today, with the guiding principles of high ceilings, ample natural lighting, and proper ventilation demonstrating sound design for any interior space. Modern architectural approaches, on the other hand, which frequently rely on mechanical means to control the environment, may not adhere to these ideals. In the present work, we focus on two indoor spaces, namely, open-plan offices and school classrooms, because these constitute spaces that are recurrently attended by the same group of people are occupied for large sections of each weekday, are typically crowded at moderate to high occupancy densities, and do not always follow Nightingale's design ideas. In short, these environments feature relatively common locations where a considerable section of the population may be at moderate to high risk of Coronavirus exposure. The findings and recommendations presented in this document, however, are applicable to practically all interior environments, and we recommend that the guiding principles be broadly implemented. We note that the findings are based on data concerning the SARS-CoV-2 variants dominant in 2020 and the increasing spread of more transmissible SARS-CoV-2 variants (Mingotti, et al., 2020).

5. The influence of occupancy behavior on indoor air movement:

Mingotti, et al. (2020) addressed implications for the spread of Coronavirus causes by the influence of the behavior of the occupation on the movement of indoor air: implications for the propagation of Coronavirus. The movement of people inside closed spaces leads to considerable air disorder and % aerosol. Although aerosols greater than about 10μm might, in some settings, settle space relatively quickly and can therefore be dispersed by the movement of people, smaller aerosols – e.g., less than 5µm – can remain airborne for several tens of minutes and maybe most strongly affected by this dispersion (Mingotti, et al., 2020). Mingotti, et al. and Wijk, et al. (2020, 2018) said that this dispersion can dominate another dispersion process if there is a sufficient frequency of people passing through a space. People have widths typically in the range of 0,300.5 m and move at speeds of 1–2ms−1 even when walking, and this leads to a highly turbulent walk, with a Reynolds number of about 105. The mixing associated with this walk in corridors, meeting rooms, school classrooms, or other spaces with relatively high people density and movement – even with 2 m spacing – may be key for quantifying the aerosol dispersion prior to it being ventilated or settling out from the space (Mingotti, et al., 2020; Wijk, et al., 2018).

Indeed, because most buildings have ventilation timeframes of 10–20 minutes, 5–10 air changes per hour, and the settling time of small particles – less than 10m – is equivalent, the aerosols may be mixed by the walks of several persons. In a supermarket, for example, a cloud of infected aerosol may be mixed by the walks of between 20 and 120 persons travelling along an aisle every 10–30 seconds. This mixing results in a more uniform, but lower aerosol concentration space, thus increasing the risk of exposure to certain aerosols for people who will subsequently pass from the corridor, even though the amount of aerosol may be reduced, the risk of infection from any virus found in these aerosols is proportional to the dose and thus the amount of aerosol to which they are exposed. Laboratory simulations of the dispersion of dye clouds and suspended particles have been performed in a liquid-filled channel of 1.04 × 0.10 × 0.20 m, as a model of a corridor. Shaping the movement of people, 0.015-0 cylinders of radius.050M were returned and in advance on the canal, with 0.1-0 speed.2ms−1, therefore providing a dynamically similar flow regime for the flow of fells of people's wakes (Mingotti, et al., 2020).

The data shows that the movement of the cylinder conducts an effective dispersion coefficient for the next mixture, which provides the base for a theoretical model. In experiments with background ventilation along the corridor, in addition to the people-focused mix, a wave of dilution migrates down the aisle after the release of infected aerosol along the corridor, but the dispersion associated with people movement causes upstream aerosol upstream in the dilution wave, delaying the efficiency of ventilation. In Figure 1a, B, images at the next time of an experiment illustrate the dispersion of a cloud of dye along the channel. In figure 1C, concentration data of a number of the experiments boil down to a simple dispersion model (Mingotti, et al., 2020). By reducing the size of a building, we find that the typical mixing rates associated with people in the school/corridor depend on the frequency of the passage of people. With a person who walks along the corridor/corridor all 10-the 40s (Choudhary, et al., 2010; Wijk, et al., 2018), this corresponds to a dispersion coefficient in the range 0.05-0.2m2 S-1 (Wijk, et al., 2018), so that for a period of 600-1200 s, the aerospace aerosol can range from about 5-15 m along the corridor. Calculations by Bhamidipati and Woods based on Mingotti, et al. (2020) developed a simple calculation model for the dispersal of aerosols in a building by a stream of individual people moving through a building, modeling the careful blend produced by each. This led to a series of simulations of aerosol-cloud dispersion as people pass along a corridor. Figure 2 shows an aerosol concentration with time, over a period of 15 s as an infected person reaches a breath corridor (Mingotti, et al., 2020).

A series of local aerosolized air clouds breathe from infected persons, and these are therefore dispersed because of the mixture produced by the continuous flow of people who follow the infected person. Models of different types of buildings are in continuous development, but the key result is the efficacy of mixing produced by the movement of people, which can lead to widespread (Dispensary) of the small aerosol produced by an infected person. This has railway implications for job levels in stores and corridors of classrooms and offices in terms of risks of exposure to small aerosols due to the repeated passage of people. The combination of aerosol settling, and space air ventilation generally leads to a residence time of small aerosols of different tens of minutes; numbers play a role in infection transmission, which depends on the source strength – i.e., the number of infectious people presented, and the residence time – i.e., as regulated by the ventilation rate, then the continued presence of the infectious and healthy people may provide a pathway for transmission (Mingotti, et al., 2020).

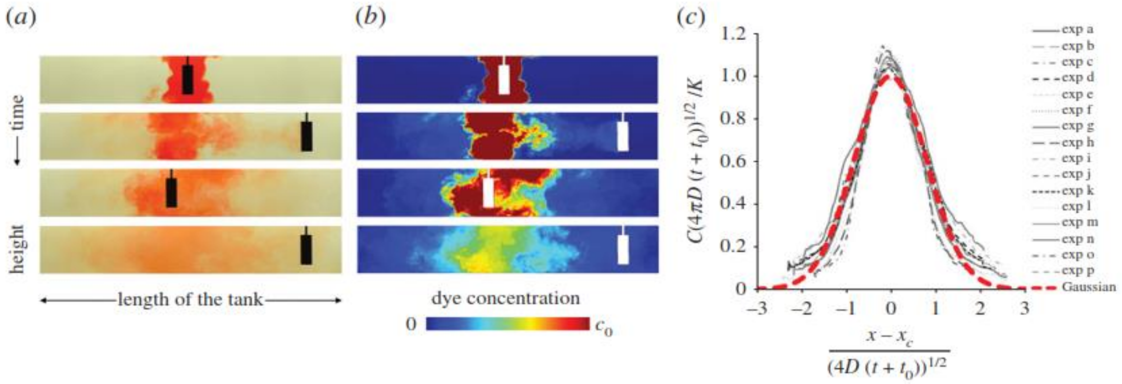

Figure 1: the depth-averaged concentration of a cloud of dye in a laboratory tank
Source: (Mingotti, et al., 2020)

Fig 1:(a, b), Images show the depth-averaged concentration of a cloud of dye in a laboratory tank. This evolves in time owing to the mixing produced by the repeated motion of a cylinder, representing the movement of people in a corridor. In (a), pictures of the tank are shown as captured during an experiment. In (b), false colors are used to represent the dye concentration field in each of these pictures, with red being the maximum concentration and blue showing the absence of dye. The white rectangle on each image in (b) illustrates the position of the cylinder at that time. (c) The collapse of the experimental data of the depth-averaged dye concentration to a continuum model of the concentration of the dye along the channel. The y-axis shows the dimensionless concentration, at each time-scaled relative to the theoretical value in the center of the channel at that time, and the x-axis shows the dimensionless distance along the channel, scaled with the predicted diffusive spreading along the channel at each time (Mingotti, et al., 2020).

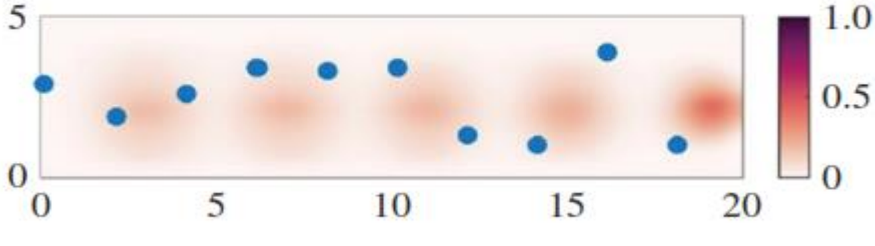

Figure 2: The mixing of individual clouds of infected aerosol
Source: (Mingotti, et al., 2020)

Fig 2: The image shows the mixing of individual clouds of infected aerosol, dyed different shades of red, and normalized relative to the initial concentration as seen in the legend. The corridor is 5 m wide (y-axis) and 20 m long (x-axis), with people (blue dots) moving from left to right along the corridor. In this simulation, the along-corridor people spacing is 2 m and they move with a speed of 1.5 m s−1, while the clouds of aerosol are produced by one person moving down the corridor, so the older cloud, at the left-hand end of the corridor is more dispersed than that on the right – calculations by Bhamidipati and Woods based on (Mingotti, et al., 2020).

6. Ventilation guidance for educational indoor rooms:

The indoor concern is that buildings become less ventilated with less supply of outside air to maintain hot conditions inside. The propagation of COVID was widespread in domestic environments, which often lack mechanical ventilation, and it's advisable to keep the windows/fans even slightly open – or, if at all, to use, what is called "drip vents" – can help reduce the spread, especially in shared rooms. Recirculating ventilation systems as a proportion of indoor air, mainly to temper the outdoor air temperature without increasing energy consumption is common, but it is Crucial to consider only the flow of outside air and how to contribute to the ventilation rate in Supplementary Electronic Materials, the benefits of increasing Internal surveillance of the environment, in particular external supply rates indicated via CO2 levels. Many works have evaluated the effects of CO2 on human physiology without any negative aspects, consequences are associated with low levels of CO2 and a certain level of performance at high levels (Mingotti, et al., 2020; Perez, et al., 2018). However, simply recommending that CO2 levels be kept as low as possible is not unhelpful because of fixed heating and other constraints. CO2 levels not exceeding1000ppm within an indoor space broadly indicate that the outdoor air supply is likely to be suitable for mechanically ventilated offices and classrooms – e.g. taking a person's CO2 production rate to be approximately 6 ml s−1 p−1 and CO2 levels in the ventilating outdoor air (Perez, et al., 2018).

7. Strategies for improving indoor quality in educational buildings

This section explores some of the additional measures available to mitigate the risk of aircraft. Transmission of Coronavirus in indoor environments. Through current work, we use "Airborne "Transmission to refer to the transmission by smaller particles that can be suspended in the air for a considerable period. By 'droplet' transmission, we mean the short-range transmission via larger droplets that fall to the surface in seconds and a few meters from the infected person. The risk of air transmission inside can be mitigated by the dilution of the interior Air for pure air outdoors. This requires a ventilation system for which the air can be increased or the installation of secondary ventilation systems. Significantly increasing the ventilation in a space is often impractical. In addition, to reducing the risk of infection by a factor, the ventilation rate must be increased by the equivalent factor. Increasing the outside air volume becomes especially difficult in winter without compromising the comfort of occupants or energy use – due to increased heating load. These factors limit the ability to reduce risk by increasing ventilation. The transmission mechanisms of Coronavirus are not yet well understood. Reducing the risk of infection to zero is not possible – unless there is a global eradication, therefore, all available sizes must be taken to obtain the greatest risk reduction. In the absence of or to supplement increased ventilation, other engineering control measures may be used (Satish, et al., 2012; Zuraimi, et al., 2011). Some of the available sizes are discussed below:

(a) Air filters or cleaners

The effectiveness of the filters and air detergents is probably very sensitive to their position in one piece. Depending on the size, shape, and flow of soil of the reasons in a room, some parts of the room may never be able to reach the gadget. In the worst-case scenario, the gadget just recirculates the same little volume of air throughout a much bigger space. As a result, while these devices frequently claim that they provide specific air changes per hour similar to clean air, this is only true if the air drawn by the device has not already been cleaned. Such devices are likely to be beneficial in smaller, poorly ventilated rooms; but, for bigger spaces, an awareness of air circulation patterns in the room is necessary to ensure the efficiency of the device. Care should be taken when deciding which filter/air cleaner to use as many appliances have stated that it was found to be having a limited effect (Satish, et al., 2012; Zuraimi, et al., 2011). HEPA filters are often recommended as better effective technology that is currently available (Siegel, 2016).

(b) Customized ventilation

Personalized ventilation (PV) provides pure air directly to the respiratory zone of an occupant of a camera via a device installed in their workstation. A certain minimum speed is required for air introduced to penetrate the convective flow guided by body heat (Zuraimi, et al., 2011). Additionally, a large target area is desired to accommodate occupant movement. The required pure air supply rate can therefore be high. While studies have shown that PV can be effective in reducing Risk for occupants during their workstations (Melikov, 2004; Zuraimi, et al., 2011), protection is not provided to the occupants when far from their workstations. Indeed, photovoltaics can facilitate the transport of exhaled pathogens to other occupants (Melikov, 2004). Installation of a custom device to provide the necessary air for each office occupant is also likely to be expensive and impractical. Alsaad; the ductless photovoltaic system is a stand-alone system, independent of the building ventilation, which transports cool air from the lower part of the room and delivers it to the Respiratory area of the occupant. This provides a much cheaper system that is much easier to install. However, the CFD study presented by Alsaad and amp; Voelker suggests that it is only effective when the PV is not being used by the infected occupant. Further, a system that transports air from the lower part of the room to the breathing zone risks transporting virus-laden Drops that could otherwise deposit on the floor. PV may be more viable in scenarios where the occupant is required to stay at their workstation for the duration of their turn (Melikov, 2004).

(C) Desk and ceiling fans

While desk or ceiling fans do not enhance the bulk supply of outdoor air, they can be used to increase the air mixture in a room, which can lead to a more homogeneous distribution of virus particles. When areas of stagnant air are identified (or suspected), a fan can be used to increase mixing with the larger space, potentially reducing the risk of building up crusader particles inside the stagnant area. The localized (relatively) high-velocity airflows produced by desk fans may result in increased resuspension of virus-laden particles and this risk must be taken into account. However, studies have found that using either desk or ceiling fans to increase air mixing within a room can lead to the largest deposit rates (Bolashikov and Melikov, 2009; Melikov, et al., 2002). These experiments use drops of oil (Alsaad and Voelker, 2020). Cigarette smoke particles (Mosley, et al., 2001), and a combination of oil, salt, and incense droplets under controlled laboratory conditions. However, deposit rates may vary depending on the order of magnitude depending on the particle size, room surface-to-volume ratio (which was varied predominantly via the inclusion of furniture), and the velocity and turbulence of the airflow in the space (Xu, et al., 1994).

In general, the removal of airborne particles by deposition is likely to be much less than by ventilation, however, for poorly ventilated rooms these rates can be comparable, particularly for larger particles (greater than 1μm). It is unclear whether the results of these studies result in increased charged particle deposition rates of COVID19 under real-world conditions. The impact of changing deposition rates on the risk of surface transmission via fomites is also unclear. Owing to this uncertainty and the potential risk of increasing the re-suspension of virus-laden Particles inside the space, the use of office fans is generally not recommended. However, when a stagnant zone is evident, either via intuition (e.g. Sheltered spaces such as reading nooks Inside classrooms and open space breakdown spaces) or via CO2 monitoring concentrations, the benefit of using a table fan to increase mixing with the largest space can overcome potential drawbacks. When fans are used in this capacity, they must be oriented. This increase in the mixture is obtained between the stagnant area and the surrounding space – where the outside air supply must be checked (Alsaad and Voelker, 2020; Xu, et al., 1994).

8. Similar Studies

Because of that, the subject of the research is very recent that previous studies in it are still rare and their results are still being tested in order to ensure their accuracy, there are three studies that are considered the closest to the goal to be achieved from the research and also the most accurate in relation to other studies in the field because they primarily contain the numerical measurements and their semantics make it more realistic. In this section, these studies will be reviewed, and an aggregated method based on them will be extracted with its end to be applied to the case study.

8.1 Rhode Island Department of Health

It is a US proposal presented by (State, 2021) that introduces a guide to improving airflow, ventilation, and air filtration to help prevent the transmission of the Coronavirus. This proposal is mainly based on the idea that Coronavirus can be spread by droplets and small particles which come out of people infected with the virus through the air. Other people may inhale these droplets and particles, or they may settle on their eyes, noses, or mouths. In some cases, droplets and particles may contaminate surfaces they fall on in some cases. The study developed an integrated strategy aiming at reaching best practices for improved ventilation to stop the spread of the Coronavirus Virus through the air, see figure3. The strategy is based on:

8.1.1 Understand ventilation requirements: Each facility has unique requirements for enhancing ventilation and airflow into and out of the building/space. When evaluating a ventilation technique, consider the number of people entering and exiting the room at any given moment, the amount of activity in the area - e.g., if they are breathing heavily, talking loudly, moving around, or sitting still, the availability of movable windows, and other considerations. Knowing a facility and the factors that contribute to good or bad ventilation will assist in developing an effective ventilation strategy (State, 2021).

8.1.2 Layered defenses: There are a variety of strategies to limit and mitigate risk to improve air quality and safety. A layered defense strategy entails using several different techniques to stop Coronavirus from spreading at the same time. Based on community transmission levels, best practices predict that this method will help limit and contain the spread of Coronavirus in our communities.

8.1.3 To be familiar with systems: Each structure and situation are distinct. Full audits of mechanical systems, air filtration and ventilation, plumbing systems, and space availability will offer the data needed to identify gaps, solutions, and possibilities to make spaces safer for everyone.

8.1.4 Improving air circulation: The best techniques are to increase outdoor air ventilation instead of recirculated air and to increase air filtration for the ventilation and filtration system as much as feasible. As much as possible, using outdoor locations for activities should be considered. Tents, platforms, and other temporary structures are used in areas close to buildings, such as courtyards, play areas, and parking lots, by some jurisdictions for such activities.

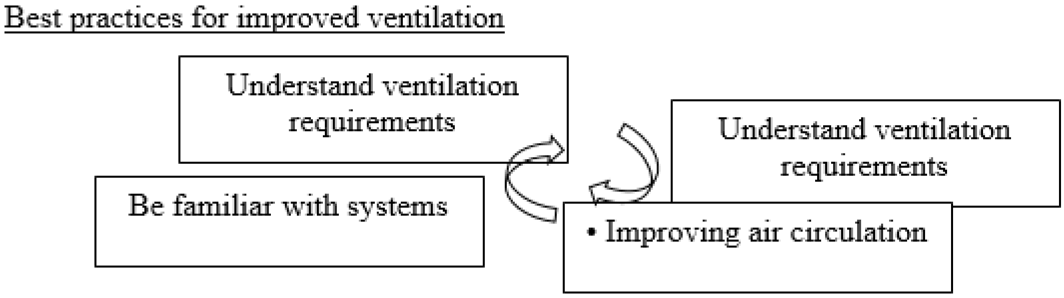

Figure 3: Rhode Island Department of Health proposal
Source: data processed by the authors from (State, 2021)

In order to achieve the general and aforementioned goals of obtaining indoor air quality for architectural spaces, the study suggested a number of strategies for heating, ventilation and air conditioning systems to reach these goals. According to the study, Coronavirus transmission in most commercial facilities at standard densities of occupants should be acceptable, limited only if HVAC systems have a minimum of four to six air changes per hour – ACH – based on square footage/volume of space, no less than 15 cubic feet/0.424753 cubic meters of ventilation air per minute – CFM – per person, and use filters with a Minimum Efficiency Reporting Value of 13 – MERV13 – or better and/or use filters with a Minimum Efficiency Reporting Value of 13 – MERV13 – or better and/ Lower-filtration HVAC systems should use more outside air or incorporate extra air filtering.

8.2 Centers for Disease Control and Prevention

The study is conducted by CDC (2021) to minimize SARS-CoV-2, the virus that causes COVID-19, the CDC suggests a multi-layered approach. To decrease the spread of disease and the danger of exposure, this strategy employs a variety of mitigation methods, including changes to building ventilation. Physical separation, wearing face masks, hand hygiene, and immunization are all part of the multilayer strategy, in addition to improved ventilation.

The following is a list of ventilation measures that can assist to reduce viral particle concentrations in the air. They are a collection of "tools in the risk mitigation toolbox," each of which can help reduce risk. Multiple tools being used at the same time is in line with the CDC's tiered approach and will improve the overall effectiveness of ventilation interventions. These ventilation measures can minimize the danger of viral exposure and illness spread, but they cannot entirely remove risk.

8.2.1 Tools to Improve Ventilation

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers – ASHRAE – Guidance for Building Operations During the Coronavirus Pandemic is used in some of the required treatments. Not every intervention will be effective in every situation. When expanding outdoor air ventilation in heavily polluted areas, exercise caution.

8.2.2 Tools identifying ways to improve ventilation

Increase the introduction of outdoor air to lessen or eliminate HVAC air recirculation, open external air dampers beyond the minimal levels. This has little effect on thermal comfort or humidity in mild weather. However, in cold, hot, or humid conditions, this may be difficult to accomplish, necessitating the assistance of an expert HVAC technician. Increase outdoor air movement by opening windows and doors when the weather permits. Do not open windows and doors if doing so poses a safety or health risk - e.g., risk of falling, triggering asthma symptoms - to occupants in the building. Even a slightly open window can introduce beneficial outdoor air.

Use fans to increase the effectiveness of open windows to safely achieve this: the location of the fan is critical and will change depending on the room arrangement. Avoid positioning fans in such a way that contaminated air can travel directly from one person to another. One useful method is to exhaust room air to the outdoors using a window fan, which should be mounted safely and securely in a window. This will allow you to bring in fresh air from outside the room through other open windows and doors without creating powerful room air currents. Other fan systems, such as gable fans and roof ventilators, can achieve similar outcomes in bigger complexes. Ensure ventilation systems to operate properly and ensure that each location has adequate indoor air quality for the present occupancy level. Rebalance or adjust HVAC systems, when possible, enhance total airflow to occupied locations.

Turn off any demand-controlled ventilation – DCV – During occupied hours, controls that limit air supply based on occupancy or temperature. Set the fan to "on" instead of "auto" in homes and buildings where the HVAC fan may be regulated at the thermostat, which will run the fan constantly even when heating or air conditioning is not necessary. Improving central air filtration to increase the size of the air filtration external icon as much as possible without affecting design airflow. When external air distribution options are limited, increased filtering efficiency is especially beneficial. When the building is crowded, making sure the restroom exhaust fans are working properly and at maximum capacity.

To improve air cleaning, using portable high-efficiency particulate air – HEPA – fan/filtration systems is crucial, particularly in high-risk places like a nurse's office or areas frequented by people with a higher possibility of having Coronavirus and/or an elevated risk of obtaining Coronavirus. For more information about HEPA filters and portable HEPA air cleaners. It should be noted that portable air cleaners with filters that are less efficient than HEPA filters are also available and can help clean the air in a room. They should, however, be properly labelled as non-HEPA units.

8.3 ASHRAE Epidemic Task Force

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers –ASHRAE– was formed in 1959 when the American Society of Heating, Refrigerating, and Air-Conditioning Engineers – ASHAE – and The American Society of Refrigerating Engineers – ASRE – merged. ASHRAE Epidemic Task Force is initiated to supply the knowledge and experiences concerning the HVAC systems of operating commercial office buildings under epidemic situations necessitates a holistic approach throughout the crisis and the eventual return to a new "normal" once the public health emergency has passed. This approach explains seven fundamental steps that can be taken in business buildings to decrease SARS-CoV-2, the virus that causes Coronavirus, exposure. This material is based on information that was accessible before August 16th, 2020. It's likely that the document's content will be altered as new information becomes available.

ASHREA intended to develop an epidemic plan that will guide Coronavirus prevention efforts. This strategy would be reviewed and updated on a regular basis, by following relevant regulations and federal guidelines, developing the plan of ASHREA can be resulted. The Plan is based on several goals, lower the risk of infection spreading among building inhabitants, keep the HVAC and building service systems in good working order, minimizing impact on building occupants and visitors, and communicate risks and precautions being taken with occupants.

ASHREA recommended several guidelines on maintaining indoor air quality in order to further protect against the spread of Coronavirus infection. Reviewing indoor and outdoor environment was one of the most important of these directions. Maintaining dry bulb temperatures within the ANSI/ASHRAE Standard comfort levels is needed, because this can lower the virus's half-life decay period. Wherever possible, trying to keep the relative humidity between 40% and 60% and examining issues related to the potential for indoor condensation. If outdoor air quality is not healthy per ANSI/ASHRAE Standards, windows should not be opened, and ventilations should not be increased without using the suitable filters. The supply and return outlet placements for the critical areas inside buildings to be noted to make sure that there is no extended exposure of air flow from one person's face to the others. These areas are lobbies, elevators, stairs, toilets, conference rooms and private offices, and atria.

Finally, ASHREA stated more important guidelines concerning the systems of HVAC inside buildings to be generally taken into consideration. Determining the features of the HVAC system and analyzing the as-built and Design documents. Compile and go over the O&M manuals. Check to see if the HVAC controls are working. Ascertain that remote monitoring and alarm capabilities exist and are operational. Check and commission the HVAC systems to ensure that at least a minimum amount of outside air is available.

According to ASHRAE Standards 62.1, outdoor air dampers are properly controlled and distributed to each space. Use filters and air cleaners in combination to improve the performance of air recirculated by HVAC systems. Prior to occupancy, implement a flushing sequence or mode that operates the HVAC system to provide three equivalent clean air changes, or two hours, by recirculation through purifiers or air cleaners, or use outdoor air if there is no energy penalty and the system can accommodate the additional air flow. During the cleansing process, turn on the exhaust fans.

Consider opening windows to improve outside air quality, especially if the system can't handle filter or minimal outside air. If exhaust outlets are near pedestrian zones, provide warning signs and consider diverting traffic to avoid them. Air handling equipment's cooling and heating coils, condensate drain pans, and humidifiers can all get contaminated.

HVAC system design and operation can influence pathogenic aerosol transmission, but they are only one component of an infection control package. Air distribution patterns, differential room pressurization, tailored ventilation, source capture ventilation, filtration – central or local, and temperature and relative humidity control are some of the HVAC tactics that can help lower the risk of infectious aerosol spread. Through dilution of room air surrounding a source and elimination of infectious agents, ventilation with optimal airflow patterns is a primary infectious disease control approach. However, it is uncertain how much infectious particle loads must be decreased to obtain a detectable reduction in disease transmissions – infectious doses vary greatly among pathogens – and whether the costs associated with these reductions are justified. The use of high-efficiency particle filtration in centralized HVAC systems lowers the infectious particle load in the air. When these regions share the same central HVAC system and are supplied with recirculated air, this technique limits the spread of infectious pathogens. Single-space high-efficiency filtration devices – either ceiling mounted or portable – can be highly successful in reducing/lowering pathogenic aerosol concentrations in a single space when properly selected and implemented. They also achieve directional airflow source control, which protects the patient from exposure at the bedside. Advanced approaches, such as computational fluid dynamics – CFD – analysis, can forecast airflow patterns and likely flow pathways of airborne contaminants in an area if done correctly and with sufficient competence. During the early stages of a design cycle, such studies might be used as a guiding tool.

8.4 The Extracted Model

By reading previous studies in the field of moving indoor air for architectural spaces in order to raise ventilation efficiency and air change rates per hour, and by extracting their general strategies and methods used to achieve this goal, it is expected that this will help reduce the chances of infection with the Coronavirus, as the these studies depend on reducing the percentage of mist in the air resulting from breathing, speaking, sneezing and coughing of people inside those spaces. Based on these studies, the researchers were able to derive a strategy that can be applied within the architectural spaces based on circulating the indoor air, purifying it and recycling it after sterilization by what will be explained here in this section in detail.

The method extracted from the previous two studies is based on examining the ventilation rates present in architectural spaces. According to ASHRAE (2021a) a 3-step method can be performed to check ventilation rates inside buildings and increasing them for purposes of preventing infection with the Coronavirus, see figure 4. Measuring the dimensions of the architectural space, identifying the typical ACH required for the room from the related AHREA index of ASHREA (2021b), estimating cubic feet per minutes or cubic meter per minute - CFM for the room, and identifying the ventilations system required to achieve the required ACH. This method has a set of tools required for its implementation; these elements are:

- Tape measure.
- Exhaust holes/ opening like windows and doors.
- At least two fans per room to circulate air.
- Air Purifier

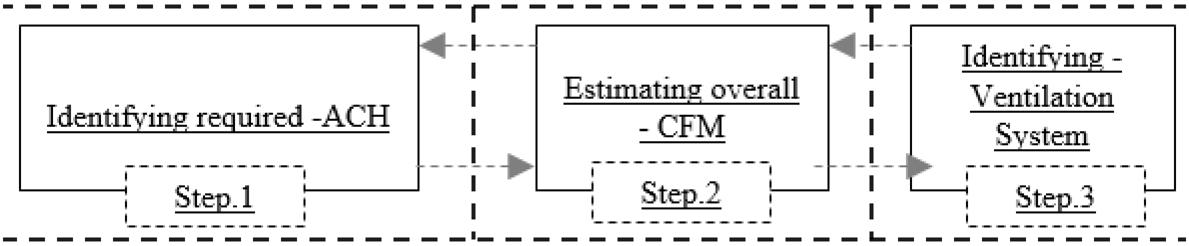

Figure 4: Flowchart of the proposed strategy
Source: the authors

According to State (2021), calculating how often the air in a space is totally replenished is one approach to quantify ventilation. This is referred to as Air Changes per Hour –ACPH, ACH. Air should be replenished at least every 15 minutes in a 30-foot/ 9.144 meters by 30-foot/ 9.144 meters room with 25 persons, which yields an ACH of 4. The ACH of 6 is best if the air is refreshed at least once every 10 minutes. Although there is no ACH standard, we do know that a greater ACH reduces the danger of illness spreading via the air. Ventilation with clean outdoor air is healthier since it eliminates viruses and other particles, as well as gases such as carbon dioxide, which everyone produces when they exhale. Because outdoor air is difficult to heat or cool, most ventilation systems employ recirculated air.
Recirculated air ventilation will not minimize the risk of Coronavirus unless the recirculated air is passed through a filter designed to remove microscopic particles. The Minimum Efficiency Reporting Values – MERV – rating of a filter indicates how well it eliminates particles of various sizes from the air. A MERV grade of 13 or higher indicates that the filter removes at least 90% of virus-containing aerosol-sized particles. HEPA – High Efficiency Particulate Air – filters are engineered to meet or surpass the highest MERV rating. A HEPA filter removes 99.97 percent of particles, including those smaller than aerosols, figure 5.

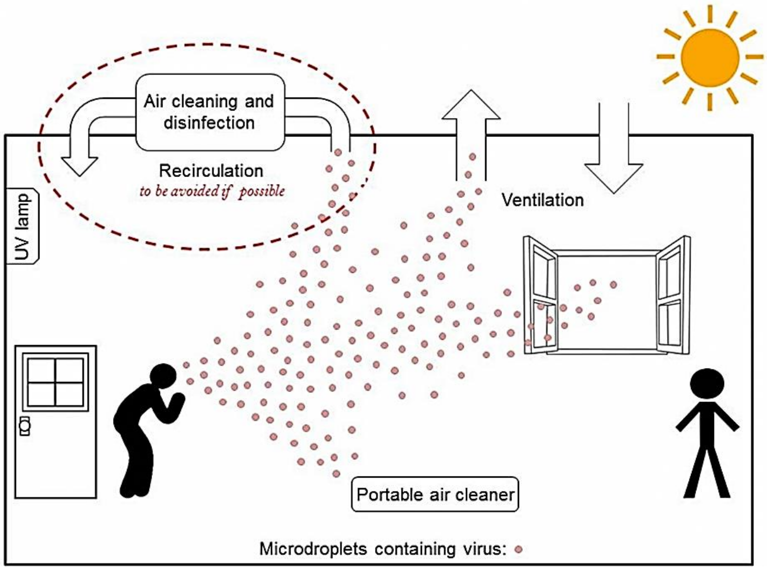

Figure 5: The proposed ventilation system within the research air circulation strategy

Table 7.2: ASHRAE ACH Standards for different building types
Table 1: Suggested outdoor air ventilation rate for different locations

Location Type		Suggested Outdoor Air Ventilation Rate (air changes per hour)
	Homes	0.35–1
	Hotel Rooms	1–2
	Offices	2–3
	Retail Shops	2–3
	Schools (except lecture halls)	5–6
	Sports Facilities	4–8
	Restaurants	6–8

Source: (ASHREA, 2022)

Table 2: Worksheet to calculate air changes per hour -ACH

Enhanced Ventilation Standards for Indoor Air Quality					
Worksheet to Calculate Air Changes per Hour -ACH					
Measurements are in Green Boxes			**Results in US Units**		**Results in Metric Units**
A	Air Flow at Fans		Linear feet per minute		Linear meter per minute
B	Width of Fans		Feet		Meter
C	Height of Fans		Feet		Meter
D	Number of Fans		Vents -or fans		Vents -or fans
E	Room Length		Feet		Meter
F	Room Width		Feet		Meter
G	Room Ceiling Height		Feet		Meter
Calculations are in Blue Boxes					

H = B x C	Area of Each Fans		Square feet		Square meter
I = D x H	Total Area of Fans		Square feet		Square meter
J = A x I	Total Air Flow in Cubic Feet Per Minute CFM		Cubic feet per minute -CFM		Cubic meter per minute - CMM
K = J x 60	Cubic Feet Per Hour CFH		Cubic feet per hour		Cubic meter per hour - CMM
L = E x F x G	Room Air Volume		Cubic feet		Cubic meter
M = K / L	**Air Changes Per Hour -ACH**		Air exchanges per hour -ACH		Air exchanges per hour - ACH

Source: Adapted and edited by the authors from (ASHRAE, 2021b)

From the previous table 2, which is concerned with calculating air change rates per hour related to the dimensions of the room under study, which is calculated based on the number of fans required and ventilation characteristics for them such as cross-sectional area and the resulting air flow rate, the researchers were able to benefit from this table in concluding the number of fans required for ventilation system that is required to obtain the rates of air change per hour – ACH to obtain the air change rates per hour required for the removal of any suspended particles or aerosols present in its air, which can be obtained from table 1.

Through the inferred rates referred above, the researchers were able to develop the necessary strategy to move the air inside the room under study in order to reduce the chances of infection with the Coronavirus, which will be explained in detail in the practical study of the research in the next section. By moving the air inside the room, the rate of air change per hour – ACH increases by an amount that helps reduce the density of suspended particles in air that carry the virus in the state of its presence, especially since the possibility of the presence of people infected with the disease is very high in the current stage of the pandemic.

9. Case Study

9.1 Given data about the case

Located at the north of the city of Mansoura on the strategic highway linking the cities of Talkha and Damietta, Mansoura Higher Institute of Engineering and Technology is the research main case study. The institute’s building is L-shaped and was built to make the short side of the building oriented to the geographical northeast direction, and the long side faces the geographical northwest direction. The main classrooms in the building are located on the side facing the northwest direction, and so that the main lectures hall is the subject of the study, figure 6. The location is characterized by the presence of many open spaces around the entire building that allow air to constantly pass around and through its inner and outer spaces. The short direction of the building facing the northeastern direction forms a positive pressure area for the prevailing winds, while the rest of the areas of the building forms a negative wind pressure, which helps the air to penetrate more inside the building increasing the efficiency of natural ventilation in all areas. Therefore, the study case possesses many components that facilitate the natural ventilation strategies necessary to conduct the research and achieve its objectives.

The study was conducted on the main lectures' hall in the building, which is rectangular in shape with dimensions 20 feet/6.10 m *35 feet/10.67 m and equipped with two entrance and exit doors, and three aluminum windows with sizes 2.20 m * 1.20 m, each equipped with two sliding sills. The hall can accommodate up to 100 students and is also equipped with a number of air conditioners, and there are no fans installed inside it, figure 7. The hall relies only on mechanical ventilation from the installed air conditioners and the windows are closed most of the time the hall is used in order to block the light, as the data show device is used for light shows for most of the lectures. The researchers measured the dimensions of the hall and determined its capabilities in terms of available natural and artificial ventilation, as well as determining the requirements for air movement in the light of the above-mentioned table 3. Then, the researchers performed the calculations for the air change per hour rate – ACH –and the overall cubic feet per minute – CFM for the hall on a day crowded with study periods and in the presence of students. These calculations were based on the steps mentioned in a table 3 in order to complete the measurements of the elements included in it and to obtain the results described below.

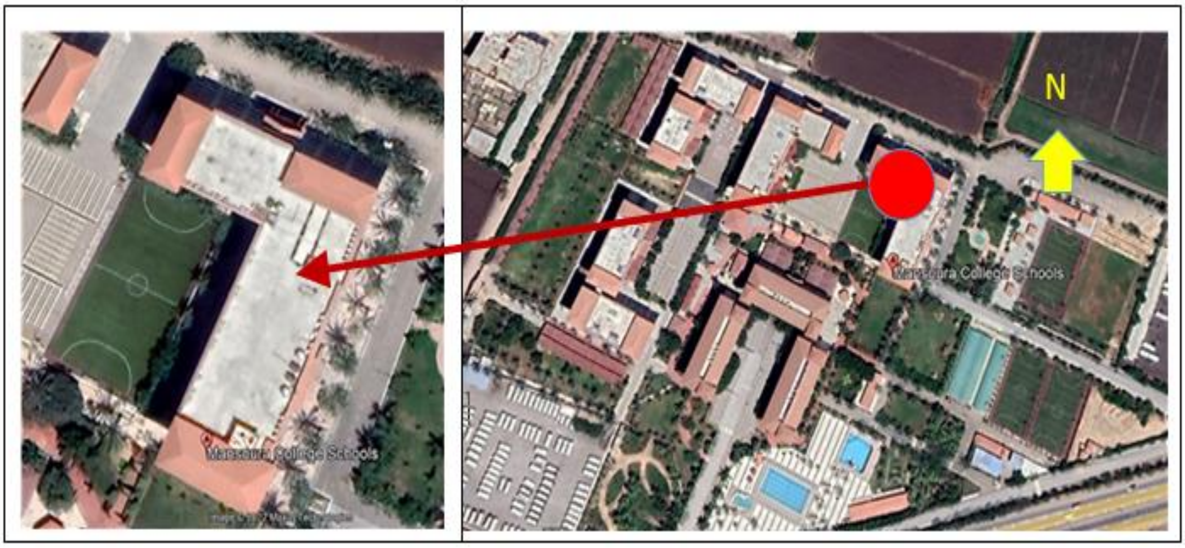

Figure 6: the site of the building under study – Mansoura College Academy
Source: adapted from (Google-Earth, 2022)

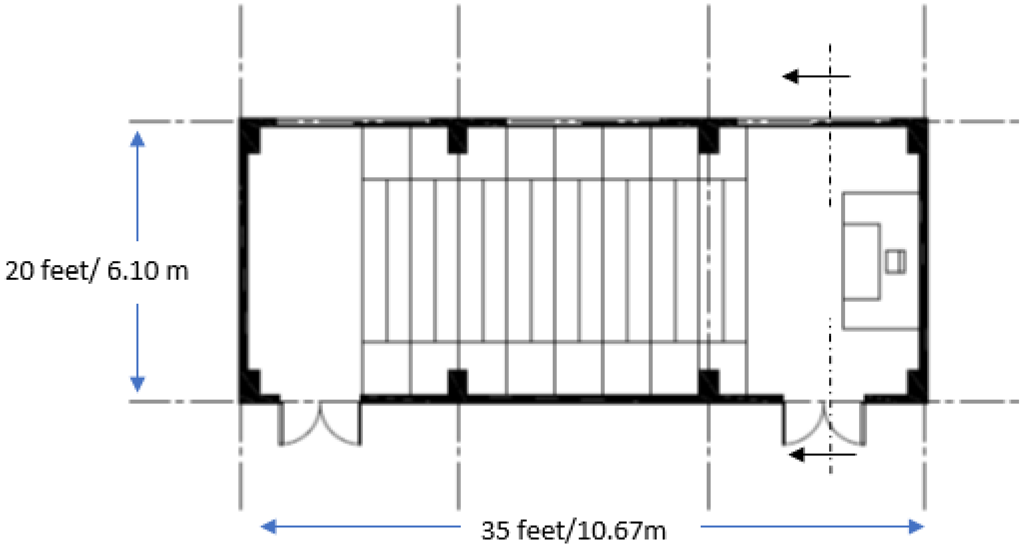

Figure 7: Plan of the lecture hall under study
Source: the authors

9.2 Applying the research model

9.2.1 Calculations

Table 3: Worksheet to calculate air changes per hour -ACH for the case

Enhanced Ventilation Standards for Indoor					
Worksheet to Calculate Air Changes per Hour -ACH.					
Measurements are in Green Boxes		**Results in US Units**		**Results in Metric Units**	
A	Air Flow at Fans	500	Linear feet per minute	152.40	Linear meter per minute
B	Width of Fans	8	Feet	2.44	Meter
C	Height of Fans	0.5	Feet	0.15	Meter
D	Number of Fans	2	Vents -or fans-	2	Vents -or fans
E	Room Length	35	Feet	10.67	Meter
F	Room Width	20	Feet	6.10	Meter
G	Room Ceiling Height	13.5	Feet	4.10	Meter
Calculations are in Blue Boxes					
H = B x C	Area of Each Fans	4	Square feet	0.37	Square meter
I = D x H	Total Area of Fans	8	Square feet	0.74	Square meter
J = A x I	Total Air Flow in Cubic Feet Per Minute -CFM	4000	Cubic feet per minute -CFM	113.27	Cubic meter per minute -CMM
K = J x 60	Cubic Feet Per Hour -CFH-	240000	Cubic feet per hour	6796.04	Cubic meter per hour - CMM

L = E x F x G	Room Air Volume	945 0	Cubic feet	267. 60	Cubic meter
M = K / L	**Air Changes Per Hour - ACH**	**25.4 0**	Air exchanges per hour -ACH	**25.4 0**	Air exchanges per hour -ACH

Source: Adapted and edited by the authors from (ASHRAE, 2021b)

9.2.2 The ventilation system according to calculation

According to the above-mentioned calculations, the lecture hall under study needs an hourly air change rate of air– ACH – equals 25.40, and this rate according to ASHAREA (2021a, 2021b) is the required rate to circulate the air inside the lectures hall in order to renew and purify it from suspended mist that may contain the Covid-19 particles. But in order to achieve this rate, the hall needs to install two fans with sizes of 8 feet/2.44 m width and 0.5 feet/ 0.15 m height and with air flow rate of 500 linear feet per minute/152.40 linear meter per minute with opening the windows for natural ventilation in order to allow the air to exit to be replaced by fresh and clean air while providing the vacuum from the inside. An electric-powered air sterilization and purification device to increase the sterilization of indoor air from any particles or droplets of the virus or any other disease transmitted through breathing, see figure 8.

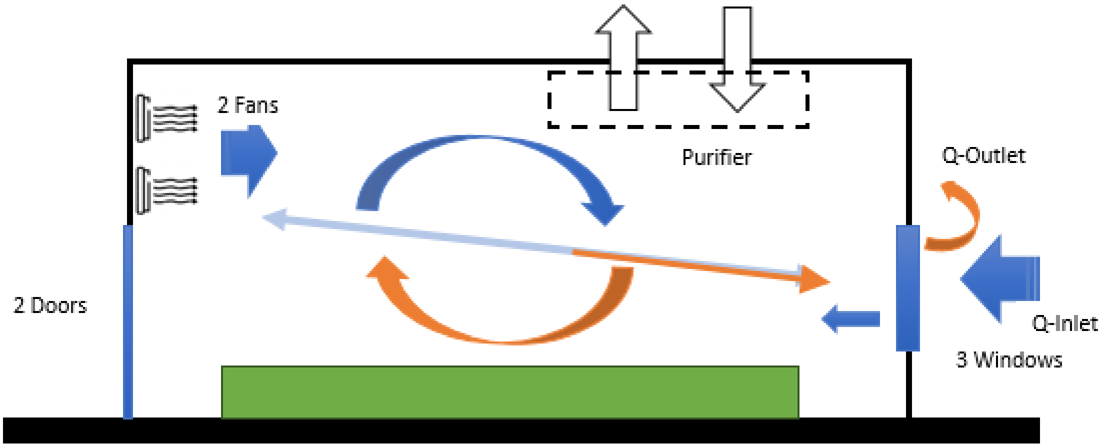

Figure 8: The ventilation system necessary to prevent the spread of infection through the indoor air
Source: the authors

10. Results

- Best practices predict that this method will help limit and contain the spread of COVID-19 in our communities.

-The numerical results that are extracted from the 3-steps method described above, which are based on the approach derived from the previous two studies examining the ventilation rates found in architectural areas, the lecture hall needs for checking ventilation rates inside it, to enhance the ability to prevent the spread of the infection with the Coronavirus. According to this 3-steps methods adopted by this research, it is necessary to measure the dimensions of the architectural space, length, width, and height, and suggesting the minimum number of required fans and air purifiers to determine the suitable air change rate per hour – ACH required for the room correspondingly to the ventilation considerations recommended by the ASHREA (2021a, 2021b) associated AHREA index, estimating cubic feet per minutes – CFM for the room, and determining the ventilation system needed to achieve the required ACH. Therefore, the following elements are necessary for the implementation of this method to prevent the spread of the Coronavirus: measuring the architectural dimensions of the room; using two fans with sizes of 8 feet/2.44 m width and 0.5 feet/ 0.15 m height and with air flow rate of 500 linear feet per minute/152.40 linear meter per minute; using air purifier; and opening the all windows and doors inside the room to allow the process of indoor air circulation to get out through openings and entering the fresh clean air to replace it in a closed and continuous movement cycle, in a way that ensures the maximum possible reduction of potential droplets and particles of the Covid virus or any other virus transmitting by air.

11. Conclusion

- Our primary focus is the air/aerosol pathway, since scattering attenuation through this pathway is the most difficult. The tests suggest that the adequate air of the outside air is crucial in helping to ensure that the reproduction number of a particular interior space is minimized and ideally remains below one.
- Higher ventilation rates may be needed wherever activity levels increase beyond desk-based work.
-By reducing the size of a building, we find that the typical mixing rates associated with people in the school/corridor depend on the frequency of the passage of people.
-Airborne "Transmission to refer to the transmission by smaller particles that can be suspended in the air for a considerable period of time. By 'droplet' transmission, we mean the short-range transmission via larger droplets.
-The risk of air transmission inside can be mitigated by the dilution of the interior Air for pure air outdoors.
-To reduce the risk of infection by a factor, the ventilation rate must be increased by the equivalent factor.
-When evaluating a ventilation technique, consider the number of people entering and exiting the room at any given moment, the amount of activity in the area.
- Full audits of mechanical systems, air filtration and ventilation, plumbing systems, and space availability will offer the data needed to identify gaps.
- The best techniques are to increase outdoor air ventilation instead of recirculated air and to increase air filtration for the ventilation and filtration system as much as feasible to improve air circulation.
- Increase the introduction of outdoor air to lessen or eliminate HVAC air recirculation, open external air dampers beyond the minimal levels.
- Increase outdoor air movement by opening windows and doors when the weather permits.
- The location of the fan is critical and will change depending on the room arrangement.
- Avoid positioning fans in such a way that contaminated air can travel directly from one person to another.
- Ensure ventilation systems to operate properly and ensure that each location has adequate indoor air quality.
-When external air distribution options are limited, increased filtering efficiency is especially beneficial. When the building is crowded, making sure the restroom exhaust fans are working properly and at maximum capacity.

-Rhode Island Department of Health proposal suggested a number of strategies for heating, ventilation and air conditioning systems to reach these goals.

- Centers for Disease Control and Prevention suggests a multi-layered approach to decrease the spread of disease and the danger of exposure.

- Ventilation measures can minimize the danger of viral exposure and illness spread, but they cannot entirely remove risk.

- The use of high-efficiency particle filtration is centralized, this technique limits the spread of infectious pathogens.

- ASHREA recommended several guidelines on maintaining indoor air quality in order to further protect against the spread of Coronavirus infection, trying to keep the relative humidity between 40% and 60% and examining issues related to the potential for indoor condensation. These areas are lobbies, elevators, stairs, toilets, conference rooms and private offices, and atria.

-According to ASHRAE Standards 62.1, outdoor air dampers are properly controlled and distributed to each space. Use filters and air cleaners in combination to improve the performance of air recirculated by HVAC systems.

- Consider opening windows to improve outside air quality.

- The air circulation system described by this research showed several factors that influence the process of preventing the spread of the Coronavirus inside educational spaces, besides location and orientation. These factors are number of openings and their sizes, the size of the room, number of users inside the room, mechanical air moving devices and air purifiers, and how to employ all these elements altogether to ensure obtaining fresh, clean, and virus-free indoor air for as long as possible. Architects should follow the guidelines of ASHAREA concerning HVAC systems and maintaining required ACH standards for certain rooms. ASHREA proposed numerous guidelines for preserving indoor air quality to better prevent against the spread of Coronavirus infection. One of the most essential of these guidelines was to examine the air movement and flow and its capability to be renewed through indoor and outdoor environments. Furthermore, clean outside air ventilation is healthier because it removes viruses and other particles, as well as gases like carbon dioxide, which everyone creates when they exhale. The researchers were able to develop a system for circulating indoor air, cleaning it, and recycling it after sterilization that can be used in architectural spaces. Therefore, it is expected that this model will constitute a successful method that can be used to prevent the spread of the Coronavirus infection, not only in educational spaces, but also in public spaces in general and in accordance with standards and guidelines of ASHAREA in this Concern.

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