Algerian Journal of Environmental Science and Technology
June edition. Vol.9. Nº2. (2023)
ISSN : 2437-1114
www.aljest.org

Airborne transmission of Coronavirus Disease 2019 (COVID-19) in Ventilated Healthcare Premise.

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ARTICLE INFO

Article History :

Received **: 02/11/2020**
Accepted **: 31/12/2021**

***Key Words*:**

Healthcare premises; CFD ; SARS-CoV-2; Staff Safety; VMC.

ABSTRACT/RESUME

Abstract: *In the present work, a numerical investigation was carried out of Covid-19 transmission from suspected or confirmed patients of Coronavirus Disease to medical staff in quarantine or isolation rooms of healthcare settings equipped with a mechanical ventilation systems. A description of various ventilation systems was presented to tackling the covid-19 dispersion. Without a science-based approach and recommended advice from researchers, such strategies of ventilation result in unknowing high-risk behavior. In this study, a Coronavirus is considered as airborne and presented by very tiny respiratory droplet. Therefore, it is necessary to investigate the effect of ventilation mode in the distribution of airborne contaminants in high risk area in public health hospitals. A Computational Fluid Dynamics (CFD) code is used to optimize the indoor air flow which carries Covd-19 released respiratory droplet assumed as aerosol and airborne and their transmission from person-to-person over short distances in patient rooms. The governing equations for turbulent flow were presented by the Navier-Stokes equations, solved with a vortex viscosity closure method using a Vreman Model for a calculation of the turbulent viscosity and Large-Eddy Simulation (LES) model of turbulent flow. Adaptive mesh refinement and Lagrangian particle methods can be utilized to simulate airflow pattern and release respiratory droplet transport under ventilation conditions in single patient rooms in order to reduce the risk of cross infection. We deduced that a preventive numerical simulation can play a crucial role in protecting the medical staff from airborne transmission of SARS-CoV-2 spreading in ventilated healthcare premises.*

I. Introduction

Coronavirus disease 2019 (abbreviated “COVID-19”) scope of infection pandemic was proclaimed by WHO on March 11, 2020 [1] (World Health Organization, 2020), respiratory tract infection caused to a new Coronavirus called SARS-CoV-2 (initially called 2019-nCoV). To avoid human-to-human transmission, infection control methods such as proper hand cleanliness and social distance are essential. This mode of COVID-19 dissemination has been observed by Chan et al. [2] and is thought to occur via close proximity as mentioned by Rothe et al. [3]. The COVID 19 pandemic is quickly spreading around the world, most notably in the North Middle East and North Africa (MENA) area, despite its lower population density in contrast to other regions of the world due to the region's inadequate health systems and war zones [4]. Early and stringent implementation of containment measures and confinement may aid in containing the spread of the epidemic and reducing the number of deaths [5]. To decrease infection risks in public facilities such as meeting rooms, schools, stores, offices, libraries, restaurants, and public transportation, adequate ventilation should be used in conjunction with other precautions in hospitals, including isolation and quarantine. The question of whether COVID-19 has the capacity for airborne transmission is now a hotly debated topic [6]. In terms of airborne precautions, the WHO recommends conventional (contact) and droplet precautions for suspected or confirmed COVID-19 patients, as well as purely aerosol-generating procedures[7].

In order to ensure that the transmission of patients, visitors and other patients is prevented by the early detection of extremely virulent patients with highly transmissible disease, all healthcare facilities should have a strategy in place to ensure the early detection of these patients in separate warning areas. Standard precautionary procedures, transmission-based precautions (contact precautions, droplet and aeronautical precautions), should be used as soon as the diagnosis is suspected as a treatment approach suggested by the healthcare personnel [8]. Placing a patient in a closed room (a quarantine or insulating chamber) for further assessment and disposal choices is a matter of urgency. Asymptomatic exposed people suspected of being at high risk by public health authorities might get quarantine. Quarantine is the separation from those that were not reasonably suspected but still not symptomatic of a person or group to avoid the spread of the disease. Quarantine is a symptom of a transmissible sickness. Isolation is used to isolate the diseased from healthy individuals with a communicable disease.

In order to establish and maintain particular conditions for primary treatment in the operation suite, intensive treatment units and insulation units for infectious illnesses in health care facilities, ventilation is frequently employed. The system is also designed to assure the compliance with quality assurance in drug and sterile supply departments for produced products and to safeguard employees, for instance in laboratories, from dangerous organisms and poisonous chemicals. This can be given by natural, mechanical or mixing techniques in a large variety of ways. In certain nations a natural ventilation of a hospital setting is known in colder temperatures or is not authorized with the USA in low pollution. A mechanical ventilation system is otherwise necessary.

Today, most contemporary hospital buildings with a central HVAC system in many places have positive pressure while in other areas, negative pressure is exerted by air flow control pressure sensors. Opening a window depressors the areas, and frequently the connected areas, causes unregulated ventilation.

If the zone spaces are positively pressurized, the room air flows directly outside, and the inside pressure drops. Zones in other rooms connected to that supply duct will also have a pressure drop, resulting in less air flow from the supply duct. Ventilation in controlled buildings is about dilution, and hospitals often add pressure control to enable the ability to control the movements of both contaminated air and "clean air" to lower the risk of spreading the contamination to other areas. If the spaces are negatively pressurized, the opposite happens when a window is opened. In both cases, effective control of the supply air is lost, thus control of the contaminated air is lost. The poorly built, operated, and maintained ventilation system makes usage during the pandemic very dangerous, as is the case in the majority of third-world nations. Even in Europe, more than two million people in Europe are infected due to Health-care Associated Infection (HAI) confirmed by Pittet et al. [9]. The risk of air pollution in a hospital is low, but may not be known until many patients, visitors and health care workers are concerned. Air distribution in a treated space, using air terminal devices, must meet specific parameters to fulfill specific parameters, such as air rate change, pressures, cleanliness, moisture temperature, air velocity and noise. One or more approaches can be used to implement exhaust: extraction: exhaust in a way that released air into the environment; relief or exhaust in such a way that air may escape from the space being treated if pressure exceeds a certain level in that space; Return to the air treatment system: exhaust in that the air is returned to it; transfer from the air into another treated area in that air passes. The present HVAC air supply systems must be maintained and confirmed to be satisfactory.

In most building ventilation settings, the low Mach number approximation to the governing equations of indoor air flow in FDS software is suitable. Musser et al. [10] provide an example of how the model may be used to assess indoor air quality. The flow pattern is designed to eliminate contaminants from the space by sweeping them upward at the source. A Mathematical model of respiratory droplets of an infected person with coronavirus by a Lagrangian turbulent model can be dispersed by the breathing action was carried out in the paper [11]. Also, the effect of respiratory droplets on the spread of COVID-19 is numerically investigated by the Eulerian approach [12]. The various phases are mathematically considered as an interpenetrating continuum in the Euler-Euler method. In reality, there is air circulation around people [13]. So, it is important to take the ambient wind and relative humidity (RH) into consideration and to calculate laden droplets to transport farther in the air, to warn that the current social distancing policy is insufficient.

Building ventilation's major goal is to supply fresh air for breathing while also removing undesirable heat and pollutants from a room. It is dedicated to creating healthcare ventilation systems in order to reduce the danger of infection from patient rooms and to safeguard medical workers who are in a vulnerable condition and feel out of control of their

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situation. COVID-19, like other respiratory diseases, may be spread by droplets and can become dangerous in close quarters. The COVID-19 virus can be transmitted by direct contact with infected people or indirect contact with surfaces in the immediate environment or with objects used by the infected person. Airborne precautions will be undertaken in addition to contact precautions.

Airborne transmission of SARS-CoV-2 is one of different modes of viral transmission, the other two being via larger respiratory droplets direct contact with infected people, and contaminated surfaces. Several published paper have considered airborne transmission of SARS-CoV-2 by quantitative viral RNA data (viral RNA copies per L of air) which they found positive air samples with different sizes (µm) [14-17]. The 5 µm WHO size threshold used to distinguish between droplet and airborne propagation is an oversimplification of the multifactorial mechanisms governing aerosol propagation and deposition [18]. Chen et al., 2020[19] study airborne transmission of SARS-CoV-2 during close contact, they considered as dominates exposure. Nonetheless the WHO continues to not give enough importance to protection against airborne virus-laden droplets. Other organizations, such as REHVA (the Federation of European Heating, Ventilation, and Air Conditioning Associations) and ASHRAE(the American Society of Heating, Ventilating, and Air-Conditioning Engineers recognizes potential hazards in indoor air and recommends appropriate ventilation controls. Ventilation plays an important role in removing the air containing the exhaled virus. This reduces the overall concentration and then the dose that the occupants inhales. But, a change of ventilation rates when needed in public buildings during the COVID-19 pandemic may differ, and may be related to each design. Proper placement of air inlets and outlets prevents viral contamination from accumulating and ensures proper dilution when needed declared Thatiparti et al., 2017[20]. SARSCoV2 virus has been shown to be stable in airborne particles with a half-life more than 1 hour declared by van Doremalen et al., 2020[21]. So sensitive people can potentially inhale it, causing an infection and further spreading the disease. An additional methods to reduce the risk transmission indoors need to be considered. even if we consider that airborne transmission occurs only with aerosol-generating procedures(AGPs), Urdaneta and Sorbello,2020[22] declared that airborne transmission of COVID-19 viral particles, AGPs, needs to be addressed with greater detail. The epidemiologic analysis, experimental measurements, and simulation results from Li et al. (2021) [23] indicate the high probability of airborne transmission in a poorly ventilated and crowded building. Here, in the face of this uncertainty a preventive numerical simulation to study a range of ventilation systems applied to building must be encouraged to minimize the cost and to predict the optimal conditions of the ventilation system whatever their modes. Computational Fluid Dynamics (CFD) is a very important tool to predict the indoor air involved airborne infection particle and their contaminant dispersion in building where many parameters are involved. Bhattacharyya et al.2020[24] used SST k-ε model to study the spread of COVID-19 virus in hospital isolation room. Srivastava et al. 2021[25] study the indoor air distribution by solving the Reynolds-averaged Navier-Stokes (RANS) equations closed with the renormalization group (RNG) k-ε model in a large office building.

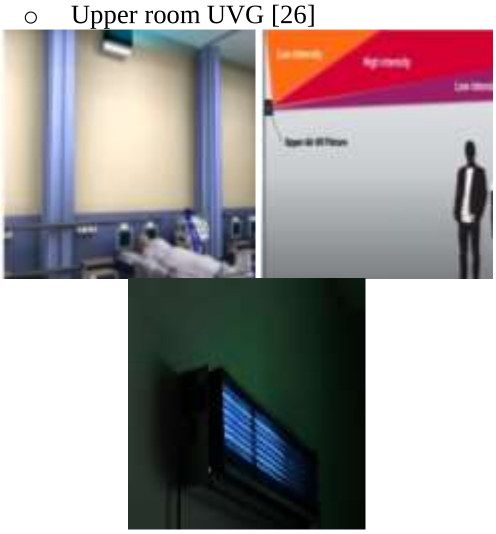
In this preventive investigation via a CFD code used to analysis the indoor air flow which carries airborne contaminants of COVID-19 virus generated from the respiratory tract of an infected person inside patient room in ventilated healthcare premises. A diagnostic time was taken as time of numerical simulation. This numerical study can contribute to sanitize the high risk area and to mitigate the spread of airborne infection of COVID-19 virus in healthcare.

II. Materials and methods

II.1. An overview about a ventilations Systems

Ventilation systems : there are lot of technologies to improve the contaminant control :

- Some are quantifiable:
  - Upper room UVG [26]



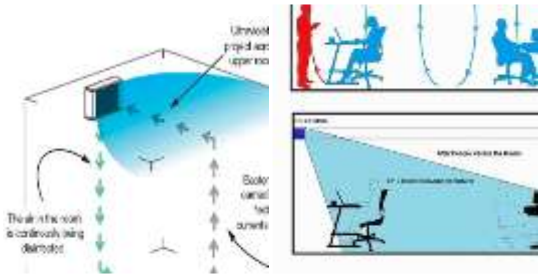


Figure 1. *Upper Air UV intensity.*

- Displacement ventilation from corners UFAD [27]

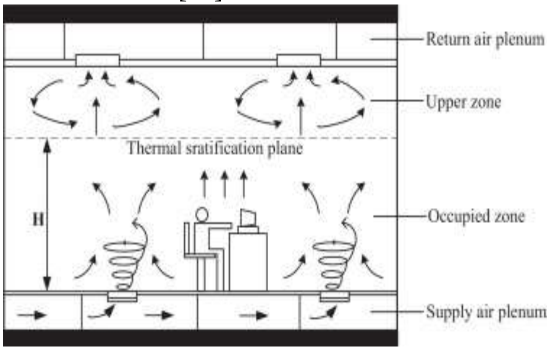


Figure 2. *Under floor air UFAD system [28]*

- In-room filtration [29]

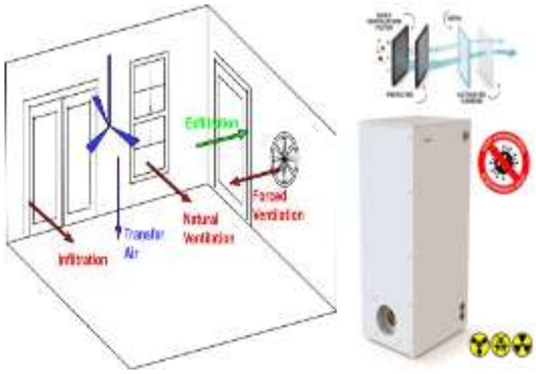


Figure 3. *Sophisticated portable air filters (PAFs).*

- Overhead Air Distribution

Figure 4. *Overhead ventilation [30].*

- Mixing ventilation

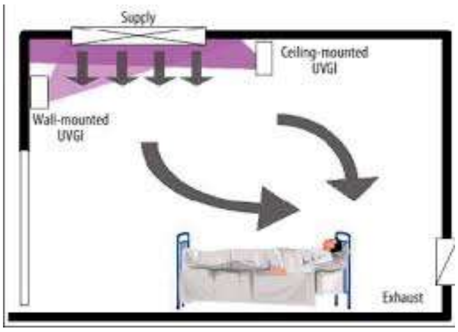


Figure 5. *Mixing Ventilation.*

- Some are new and still experimental:

In room far UVC (222 mm) [31]

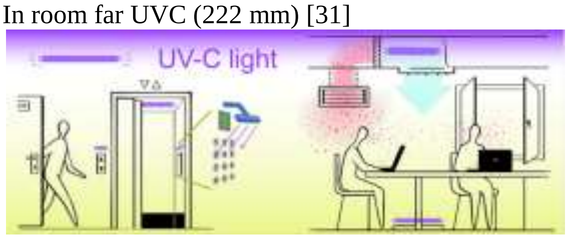


Figure 6. *UVC light as a short-term against virus.*

- Some are hard to validate:

Cold plasma /bipolar ionization [32]

- Some have potential Dangerous Bi-products:

Electrostatic precipitator (ESP) [33]

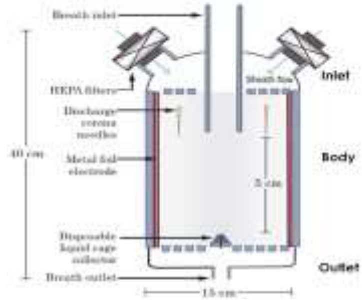


Figure 7. *Breath electrostatic sampler (BESS).*

The recirculation of air is a measure for saving energy, but care must be taken, as it can transport airborne contaminants (including infectious viruses) from one space and distribute them to other spaces connected to the same system, potentially increasing the risk of airborne infection in areas that otherwise would not have been contaminated.

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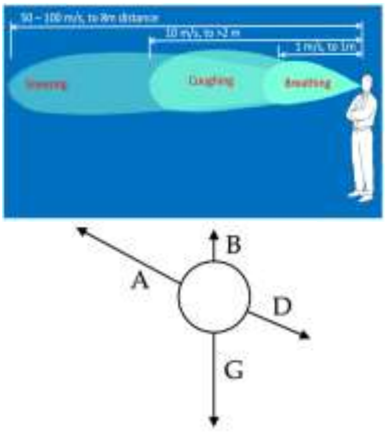

Figure 8. *The velocity and reach of aerosols generated by breathing, coughing and sneezing, and forces acting on an airborne droplet [34].*

N.B: The total force acting on each droplet is defined as F = A − D + B − G

where
A—air flow force;
B—buoyancy force;
D—drag force; and
G—gravitational force.

II.2. Mathematical Model

The computational fluid dynamics (CFD) code used in this preventive numerical simulation is FDS, a free software developed by the National Institute of Standards and Technology (NIST) that uses the Smokeview (SMV) program to display the output of FDS. In this study, a Lagrangian approach can be used to predict the airborne transmission of COVID-19 by released respiratory droplet trajectories in indoor flow under ventilation acting on droplets. However, the Euler-Euler approach is more coherent with the aerosol particles of viruses. The used software solves numerically the governing systems equation of the Navier-Stokes equations suitable for low-speed pressure-driven simulation with thermal influences using Large-Eddy Simulation (LES). A CFD program design for thermal driven flow used to model pressure driven flow with a thermal influence can potentially be done by modification of the Fortran code. Many CFD programs are available. Some are general purpose and need to be configured. Some are "pre-configured" like FDS. CFD is a standard method of predicting air distribution when the parameters are known. In this simulation, we have predicted the maximum parameters of the simulation. The reality is that the mucous particles laced with COVID will evaporate the water (rate unknown), etc. This changes the mass of the carrying droplet and can range in size from sub-micron to 100 microns. Changing the populations of different sizes will change the results of the CFD results.

Continuity equation:

$$\frac{\partial \rho}{\partial t} + div(\rho \vec{U}) = 0 \quad (1)$$

Momentum conservation equation, written in vector form, this equation is:

$$\frac{\partial \mathrm{u}}{\partial t} + \vec{u}\ \vec{\omega} + \nabla H = \frac{1}{\rho}((\rho - \rho_0) + \vec{g} + \vec{f_b} + \overrightarrow{\nabla.\tau_{ij}} \quad (2)$$

With

$$\overrightarrow{(u.\nabla)}\vec{u} = \frac{\nabla|\vec{u}|^2}{2} - \vec{u} * \vec{\omega} \quad (3)$$

$$H = \frac{|\vec{u}|^2}{2} + {}^{\rho}/_{\rho_\infty} \quad (4)$$

The shear is:

$$\tau_{ij} = \mu\left(S_{ij} - \frac{2}{3}\delta_{ij}(\nabla.\vec{u})\right) \quad (5)$$

δ_{ij} is the symbol of Kronecker:

$$\delta_{ij} = \begin{bmatrix} 1\ si\ i = j \\ 0\ si\ i \neq j \end{bmatrix}$$

S_{ij} is the stress tensor:

$$S_{ij} = \frac{1}{2}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) \quad (7)$$

Energy conservation equation:
In FDS, it is the enthalpy (h) that appears in the energy conservation relationship. For an ideal gas, this enthalpy is directly related to the temperature.

$$\frac{\partial}{\partial t}(\rho h) + \nabla.\rho h\vec{u} = \frac{DH}{Dt} - \nabla.\vec{q_r} + \nabla.K\nabla T + \sum \nabla.h_\alpha \rho D_\alpha \nabla Y_\alpha \quad (8)$$

Where Y_α is mass fraction of the specie α.
All of these equations are coupled to the ***ideal gas equation of state*** defined by:

$$H = \rho T R \sum \frac{Y_\alpha}{M_\alpha} \quad (9)$$

D_α the diffusion coefficient of the gas. R is the ideal gas constant, M_α is the molar mass of the gas, q_r is defined as the radiative heat flow, K is the thermal conductivity. Finally T represents the temperature, h is the enthalpy, H is the pressure, $\vec{g}$ corresponds to the gravity vector and $\nabla.\tau_{ij}$ is the viscous tensor.
We can still define the pressure from the Bernoulli equation in the following form:

$$\mathrm{H} = P_0 + \rho_\infty \vec{g} Z + P \quad (10)$$

It should be noted that the FDS software allows a resolution of the energy conservation equation from the source terms. Also it allows to calculate the temperature from the enthalpy. FDS used a large Eddy Simulation method LES. It has been successfully applied in the field of ventilation in buildings. the LES method can give a more complete description of the structure of the transient turbulent flow unlike the RANS codes. The closure model used in the LES method is governed by the following equations:

$$\tau_{ij} = \mu(2S_{ij} - \frac{2}{3}\delta_{ij}(\nabla.u) \quad (11)$$

$S_{ij} = \frac{1}{2}(\frac{\partial u_i}{\partial u_j} - \frac{\partial u_j}{\partial u_i})$ (12)

Turbulent viscosity μ_{LES} is given by:

$\mu_{LES} = \bar{\rho}(C_s\Delta)^2 \frac{1}{2}\left[2\,(S_{ij})^2 - \frac{2}{3}(\nabla.u)^2\right]^{1/2}$ (13)

After calculating the viscosity, we can easily calculate the thermal conductivity as well as the diffusivity by the following relations:

$K_{LES} = \frac{\mu_{LES}\,C_P}{Pr_t}$ (14)

$(\rho D) = \frac{\mu_{LES}}{Sc_t}$ (15)

Where Pr_t , Sc_t are respectively the Prandtl and the turbulent Schmidt number. These numbers are dimensionless and can be changed for any given scenario. In a basic scenario on the FDS software, these coefficients are assumed to be constant and have a value of Pr_t = 0.5.

In the FDS software, it is necessary to use a closure model to solve the systems of equations. FDS offers 4 possibilities for the calculation of the turbulent viscosity.

a. Smagorinsky model with constant coefficient

The Smagorinsky model implies that the flow of kinetic energy across space and the large scale of turbulence are in equilibrium. This model offers a relationship for turbulent viscosity in order to illustrate the temporal evolution of small-scale turbulence, with the following equation:

$\mu_t = \rho(C_s\Delta)^2|s|$ (16)

$|s| = (2S_{ij}S_{ij} - \frac{2}{3}(\nabla.u)^2)^{1/2}$ (17)

C_s=0,2 is a constant and $\Delta = (\delta_x\delta_y\delta_z)^{1/3}$ is the length of the grid.

b. Smagorinsky dynamic model

According to the same principle of the constant coefficient Smagorinsky model. This model differs in the parameter C_s which is no longer considered constant. This parameter is calculated based on local flow conditions.

c. Deardorff Model

The FDS software uses this model by default thus giving the value of the turbulent viscosity as a function of the kinetic energy according to the following relations:

$\mu_t = \rho C_s \Delta\sqrt{k_{sgs}}$ (18)

$k_{sgs} = \frac{1}{2}((\bar{u} - \hat{u})^2 + (\bar{v} - \hat{v})^2 + ((\bar{w} - \hat{w})^2)$ (19)

$\bar{u}$ the average velocity at the center of the cell, $\bar{u}$ is the average value of the velocity between cells. They are defined as follows.

$\bar{u}_{ijk} = \frac{u_{ijk} + u_{i-1,jk}}{2}$ (20)

$\hat{u}_{ijk} = \frac{\bar{u}_{ijk}}{2} + \frac{u_{i-1,jk} + u_{i+1,jk}}{4}$ (21)

The constant C_V is fixed at 0,1.

d. Vreman Model

This model is used in our various numerical simulations. Smagorinsky's model is not accurate for homogeneous turbulent flow as well as transition regions, as obtained in our simulations. This model allows the resolution of the Navier-Stokes equations with a vortex viscosity closure method, governed by the following equations:

$\partial_j u_j = 0$ (22)

$\partial_t \bar{u}_J + \partial_J(\bar{u}_I\bar{u}_J) = -\partial_t(\bar{p} + {}^{\tau_{kk}}/_{3} + v_e \partial_j{}^2 \bar{u}_I + \partial_j . 2v_e S_{ij}$ (23)

The turbulence tensor is given by the following relation:

$\tau_{ij} = \overline{u_I u_J} - \bar{u}_I\bar{u}_J$ (24)

It is replaced by the following relation:

$\tau_{kk}\delta_{ij}/3 - 2v_e S_{ij}$ (25)

Where

$S_{ij} = \frac{1}{2}\partial_i\bar{u}_J + \frac{1}{2}\partial_j\bar{u}_I$ (26)

The turbulent viscosity is given by the following relation:

$v_e = c\sqrt{\frac{B_\beta}{\alpha_{ij}\alpha_{ij}}}$ (27)

With

$\alpha_{ij} = \partial_i\bar{u}_J = \frac{\partial\bar{u}_J}{\partial\bar{x}_I}$ (28)

$\beta_{ij} = \Delta_m^2\alpha_{mi}\alpha_{mj}$ (29)

$B_\beta = \beta_{11}\beta_{22} - \beta_{12}^2 + \beta_{11}\beta_{33} - \beta_{13}^2 + \beta_{22}\beta_{33} - \beta_{23}^2$ (30)

The constant c is directly related to the constant of the Smagorinsky model

c≈ $2.5\,C_s{}^2$ and α represents the matrix of derivatives of the average velocity.

FDS, the time step is automatically adjusted to satisfy the condition of Current Friedrichs Lewy CFL <1 given by the following relation:

$\text{CFL} = \partial t\frac{\|u\|}{\partial x} < 1$ (31)

The speed components are checked at each time step to ensure that the CFL condition is satisfied.

In addition, the convective heat flow created by ΔT a difference temperature between the patient's mouth, or a body of medical staff, and the surrounding air is estimated by default by the following relationship.

q" = h ΔT (32)

The convection coefficient h, is calculated from the following correlation.

$h = max\left(C|\Delta T|^{\frac{1}{3}}, \frac{k}{L}Nu\right)$ (33)

Where C s a coefficient of natural convection. It is given by the value of 1.52 for a horizontal surface and 1.31 for a vertical surface.

III. Results and discussion

III.1 Computational domain

Health officials recommend avoiding close contact with people who are sick. An isolation facility aims to control the airflow in the room so that the number of airborne infectious droplets is reduced. This ensures cross-infection of other people within a healthcare facility is highly unlikely. A neutral or

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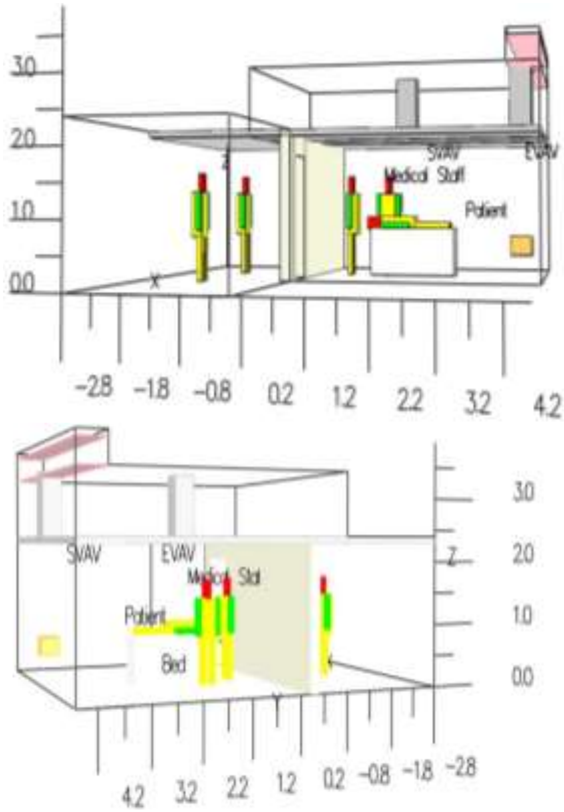
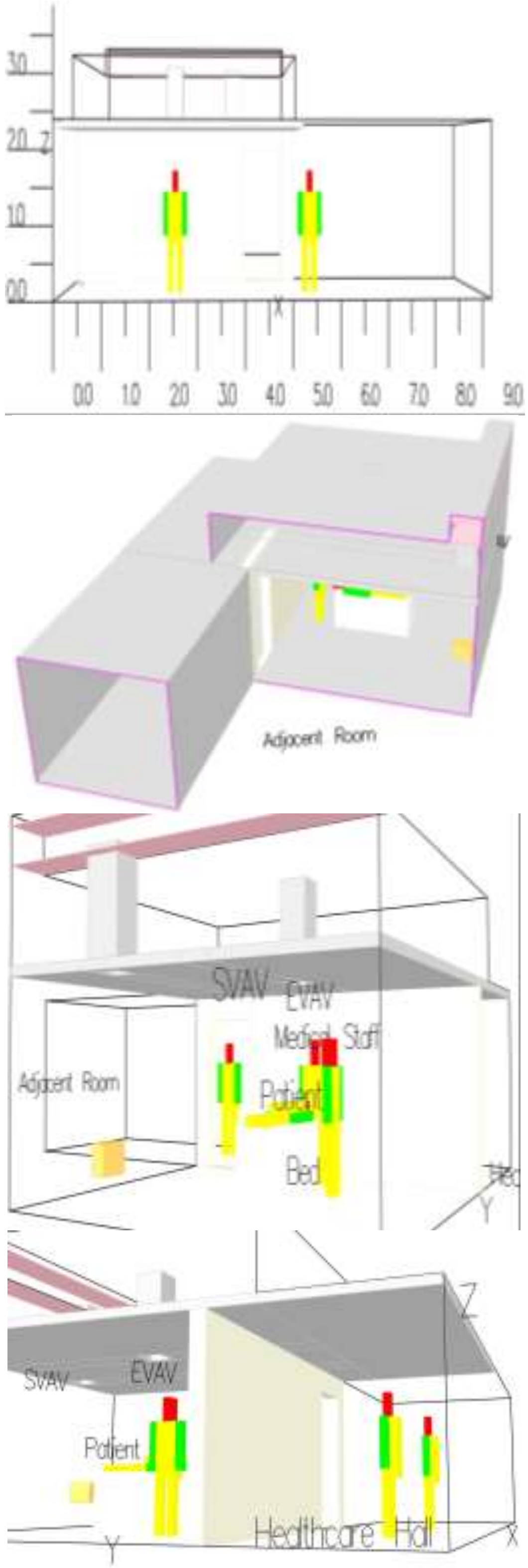
standard room air pressure, for example, standard air conditioning, protects an immune-compromised patient from airborne transmission of any infection. Negative room air pressures with additional barriers, including an Anteroom, also known as quarantine isolation, protect others from any airborne transmission from a patient who may be infected.





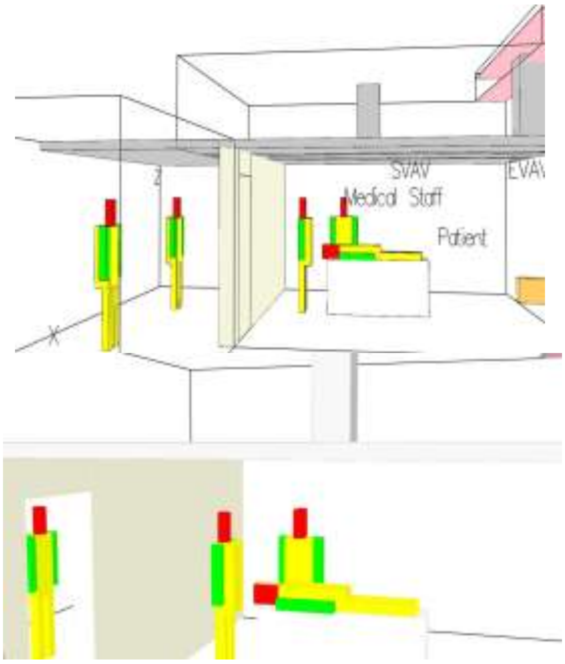


Figure 09.*CFD model of Isolation Room.*

Only CFD gives the answer because the best position for the filter box to clean the air is not necessarily in the corner. CFD simulation can potentially reveal the spread mechanisms of exhaled pollutants. A 3000 particles to get sick. If you normal breathing, 135 particles (average) will come out from a sick person. The virus is so small, the inertial forces become very low, so the particle tracing approach won't work correctly. The governing equations of all fluid flow equations, including scalar quantities and pollutant concentration, can be resolved by applying the Large Eddy Simulation Method. This method is more coherent than the k-e turbulence model because it resolves large scale and modeling small scale motion of turbulence.

The patient space in our model contains: A patient (red horizontal obstruction, Net Heat Flux=0.09KW/m^2, frontal temperature of 40.0°C to present fever), a doctor (generate heat flux of 0.06 KW/m^2) and a bed (white horizontal obstruction). A Hall healthcare between the isolation or quarantine room and the outside area include in this simulation two nurses in Healthcare Hall and one of them with a doctor (generate heat flux of 0.06KW/m^2) with respected social distancing. If we add a lamp in ceiling, it can generated a heat (0.2 KW/m^2).

A ventilation systems composed of Exhaust venturi Valve EVE placed in ceiling room above the patient (XB=3.5, 3.9,4.0,4.4, 2.3, 2.5), Supply venturi Valve SVV of fresh air placed in the best position in which a doctor during periodic diagnostic or treatment purposes can reside below it to get the fresh air (XB=2.00, 2.4, 1.60, 2.00, 2.3, 2.5). For contagious patients, filtration arrangement must be given on the supply air ducting to protect the patient from unfiltered air. Two separated chimneys of fresh air and contaminated air respectively to prevent a direct recirculation to the quarantine room fresh air enters the quarantine room from a ceiling diffuser (inlet) with ambient temperature of 20°C this values is coherent with recommended average air temperature of 20.8°C fixed . A Common Exhaust duct with pink color shared by Fans in Separate patient rooms or dwellings in the same healthcare. Healthcare hall were simulated with a closed windows because the opening windows can create an uncontrolled flow.

Coronavirus is considered as airborne and presented by very tiny respiratory droplet of orange color with a speed velocity of 0.24 m.s^{-1}. Airborne transfer means that the virus can float in the air over time and infect whomever and surrounding humans by breathing in contaminated air or by entering their eyes. Frequent coughing can complicate a situation because the virus is released more. A typical coughing duration is 0.5 seconds. Coughing characteristics are obtained from "Flow dynamics and characterization of a cough" by Gupta et al. [35]. The smaller droplets that emerge from a cough or sneeze can travel 5 to 200 times further than if those same droplets moved as unconnected particles (not in a cough or sneeze cloud). To simulate the release of viruses due to coughing or similar actions, a good model of particle tracing for fluid flow was cited in the paper by Javadpour et al. [8].

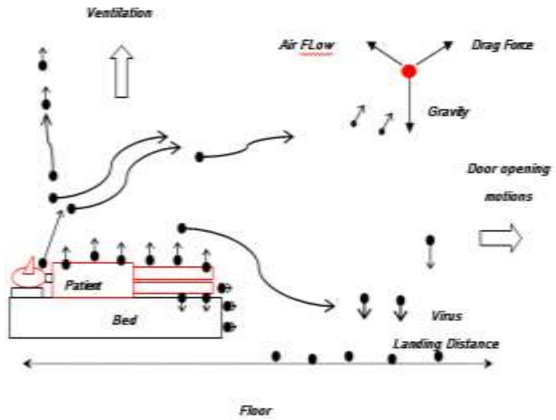


Figure 10. *An illustration of airborne COVID–19 trams with the influence of ventilation and gravity provided by Tang et al.[36], through a tiny particle suspension from an infected patient.*

In this simulation, an isolation room is not provided with an anteroom. The Victorian Advisory Committee on Infection Control [12] recommended a minimum differential pressure between the isolation room and adjacent spaces should be 15 Pa. This simulation outlines the treatment of the novel Coronavirus as Lagrangian particles. This means that each particle interacts individually depending on the acting force applied to it. This predicted numerical simulation of airborne transmission consideration reflects a serious public

ISSN : 2437-1114

health risk to the medical staff during long-term care facilities because, under the ventilation rate, COVID-19 can travel a great distance and can linger in the healthcare space for longer.

Flow field

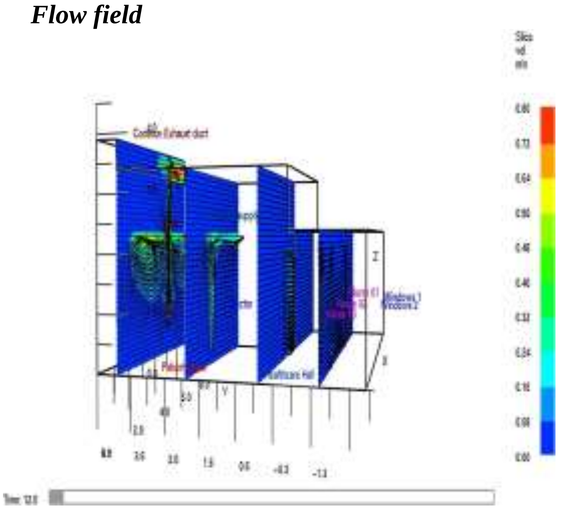
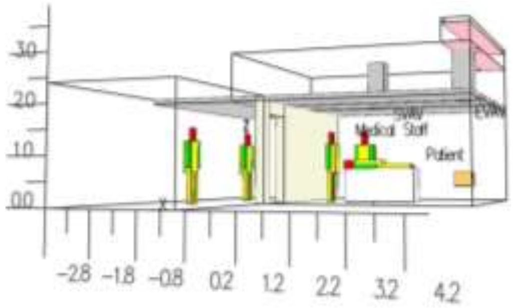


Figure 11. *Temporal evolution of flow speed around a medical staff at different transversal Y axes.*

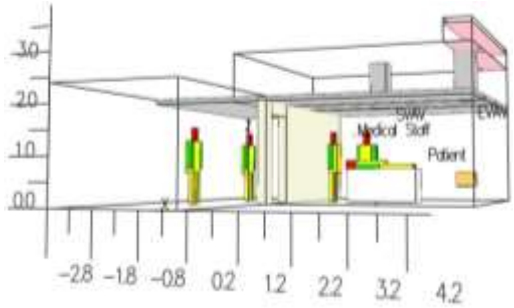
In the patient room, turbulent air mixes and dilutes the infectious exhaled air. The room air flow carries Cronavirus Covid-19 droplets, which are slowed by air resistance as they fall. Large drops ultimately settle on a surface and test their abilities. To expel contaminated respiratory droplet back into the air, a bed action is popular. Fresh air from the ventilation system and door opening actions can create vortices, which mix the air and exchange it across the entryway. A masse and heat exchange can be favored by different heat flux and frontal temperature (light, patient and medical personnel, heat generator in winter). Also, the opening (Exhaust and Supply Venturi Valve) and ventilation (windows, negative pressure of patient room) can be forced or free convection, depending on the value of Kermani's dimensionless Grashof number[11].

Virus particule spread

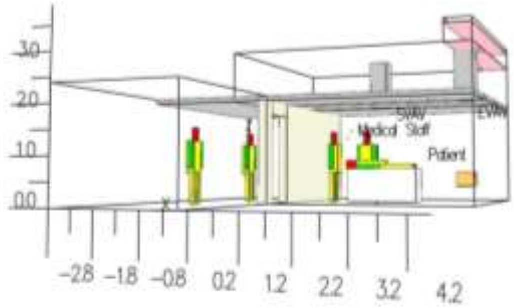
The purposes of this simulation is to present a 3D dispersion and deposition of contaminated air simulated as respiratory droplet in healthcare settings and their behavior to transmit with a direct or indirect exposure to medical staff, medical materials, environmental surfaces, devices, and equipment.



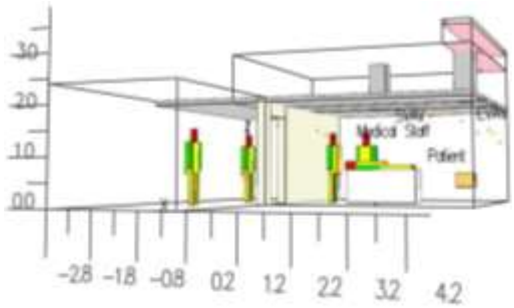
t=0.0 s



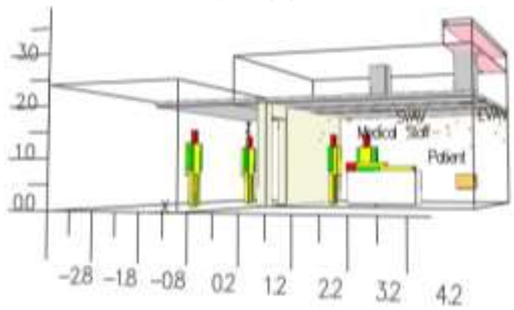
t=6.0 s



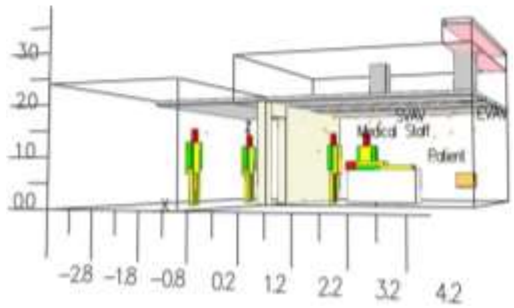
t=29 s



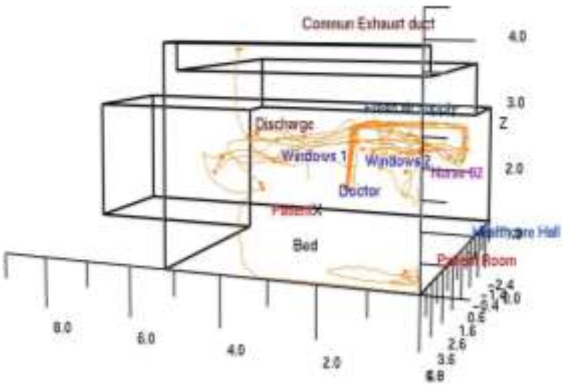
t=115 s



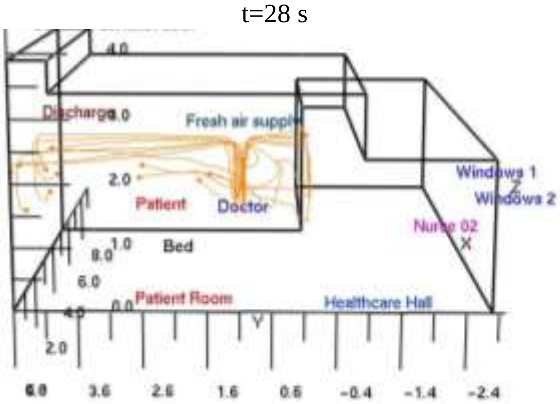
t=240 s



t=334 s



t=28 s



t=211 s

Figure 12. *Viral released respiratory droplet spread in patient room.*

People with COVID-19, spread viral droplets through coughing and sneezing. The particles can land in the mouths or noses of those nearby. A contaminated air from patient involve a virus particles were simulated by a small particles for visualization spreading as airborne. The effect of subgrid-scale turbulent fluid motion on the velocity and position of a Lagrangian particle may be accounted for using a random walk model developed by Raman et al. [13]. Figure 20 illustrate a virus spread into respiratory droplet versus a time of diagnostics, present droplets and their strikes in Figure 18. Streaks are a good way of visualizing motion in a still image (i.e., on paper) since the streak shows a history of where the particle has been.

A medical staff working in emergency rooms surrounded by coughing patients must be quick in their diagnostics to help save not only their patients lives, but their own. Preferably to work in stream flow rather than a turbulent flow with vortices due to the door crack and ventilation conditions which favorite a mixture of fresh air with airborne particles, to rising the ventilation speed of discharge duct.

The estimation of infection risk due to a contaminated hand contact with the mouth, eyes, and/or nostrils were reported by Nicas and Best [37] by :

$$P = 1 - exp\left(-\frac{IGp\beta t}{Q}\right) \qquad (34)$$

where $P$is probability of infection, I the infection numbers, G number of airborne pathogen agent liberated by patient by time unity, p the rate of pulmonary ventilation of a sensitive person, β the deposition of pathogens in the alveolar region,t the exposure time and Q the ventilation rate of the room with fresh air.

$$q_e = \frac{RT}{B}\ln A + \frac{RT}{B}\ln C_e \qquad \textbf{(4)}$$

The values of isotherms constants are presented in Table 1. From this table one can point out that the adsorption of Cr(VI) ions onto apricot stoneswas well correlated with theFreundlich and Langmuir isothermsfor the studied concentration range, which may be due to the distribution of active sites onto apricot stonessurface.The maximum adsorption capacitiy (Q_{max}) of Cr(VI) ions found in the present study was compared with those of other biosorbentreported in the literature and are presented in Table 2.

IV. Conclusion

A CFD is used to study the working fluid in healthcare which is essential for disinfection of the room air and thereby protecting the lives of doctors, nurses and healthcare workers. CFD simulation can potentially reveal the spread mechanisms of exhaled pollutants. We have obtain better insight into airborne transmission contamination to predicting airflow pattern in patient rooms and preventing the worst-case scenario. The present study showed an overview of current ventilation systems, description of measure globally to reduce the likelihood of transmission and thereby protect medical staff and healthcare premise for visitors. A ventilation in third world healthcare should be recognized as a means to reduce airborne transmission, ventilation rates should be optimized, avoid air recirculation, air cleaning and disinfection devices may be beneficial, minimize the number of people within the same indoor environment in an epidemic. A comprehension of dispersion mode from patient to their surrounding by preventive numerical simulation under different conditions with a coherent modeling might be a good addition to tackling covid-19. The numerical results is crucial tool to evaluate black points in simulated area to optimize the ventilation, stuff displacement to achieve a high degree of emergency while simultaneously reducing a contamination risk, using telemedicine when possible and limit the numbers of staff providing their care.

Perspectives

Predicting more air distribution when the parameters are known for scientific community later .The reality is that the mucous particles laced with COVID will evaporate the water (rate unknown) and the fluid in the expelled droplets also evaporates rapidly, resulting in a reduction in the size, and this rate of evaporation may depend on prevailing conditions of temperature and humidity.

Acknowledgments

We acknowledge the Algerian Research Organism DGRSDT by PRFU project, under the number [No. A11N01UN220120200010].

Nomenclature

C_s : Contaminant concentration at Exhaust Venturi Valve (ppm)
ρ: Air density (kg/m^3)
$\vec{u}$: Flow velocity (m/s)
R : Perfect gas constant (J mol-1 K^{-1})
M_α : Masse molaire of gas (g·mol^{-1})
q_r : Heat flux (J/s)
K : Thermal conductivity (W/m·K)
h : Enthalpy (J/kg)
$\vec{g}$: Gravitu (m/s^2)
H : Pressure
τ_{ij} : Viscous tensor (kg/m·s^2)
μ : Dynamic viscosity (kg/m·s)
v : Kinematic viscosity (m^2/s)
S_{ij} : Strain tensor
δ_{ij}: Kronecker symbol
P_0 : Atmospheric pressure(Pa)
μ_{LES} : Viscosity (kg/m.s)
K_{LES} : Thermal Conductivity (W/m.K)
Sc_t: Turbulent Schmidt Number
Pr_t : Turbulent Prandtl Number
Y_α: Mass fraction of gas
u : Component of the speed along the X axis (m/s)
$\bar{u}$: Component of the average speed along the X axis (m/s)
$\hat{u}$: Component of the fluctuating speed along the X axis (m/s)
v : Component of the speed along the Y axis (m/s)
w : Component of the speed along the Z axis (m/s)
∇: Nabla operator

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Please cite this Article as:
Miloua H., Airborne transmission of Coronavirus Disease 2019 (COVID-19) in Ventilated Healthcare Premise, ***Algerian J. Env. Sc. Technology**,* **9:2 (2023) 3134-3145**