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SARS-CoV-2 computer simulation of sterilization via electrical resistance in air conditioning

Simulação computacional da esterilização do SARS-CoV-2 via resistência elétrica em ar condicionado

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Abstract
In search of reinvention in the middle of the pandemic, an equipment adapted from a system that controls morph for indoor environments that have air conditioners is proposed. This paper presents a study via computational modeling to test the effect of electrical resistance as an air filter against SARS-CoV-2. The mode of transmission of SARS-CoV-2 includes, for example, transmission via contact, droplets, and aerosols present in indoor humidity. Therefore, aerosol spread of SARS-CoV-2 is similar to the indoor spread of the morph. The result shows that the system works by eliminating the humidity in the air containing SARS-CoV-2. What we are trying to demonstrate is that an electrically resistive filter controls the spread of the virus in air up to 10 cubic meters in size indoors. This system does not replace existing filters, but is a piece of equipment to help control SARS-CoV-2.
Keywords: computer modeling, contamination, electrical resistance, virus

Resumo
Em busca de reinvenção em meio à pandemia, propõe-se um equipamento adaptado de um sistema que controla mofo para ambientes internos que possuem ar condicionado. Este artigo apresenta um estudo via modelagem computacional para testar o efeito da resistência elétrica como filtro de ar contra o SARS-CoV-2. O modo de transmissão do SARS-CoV-2 inclui, por exemplo, transmissão por contato, gotículas e aerossóis presentes na umidade interna. Portanto, a disseminação em aerossol do SARS-CoV-2 é semelhante à disseminação interna do morfo. O resultado mostra que o sistema funciona eliminando a umidade do ar contendo SARS-CoV-2. O que estamos tentando demonstrar é que um filtro eletricamente resistivo controla a propagação do vírus no ar até 10 metros

cúbicos de tamanho em ambientes fechados. Este sistema não substitui os filtros existentes, mas é um equipamento para auxiliar no controle do SARS-CoV-2.
Palavras-chave: modelagem computacional, contaminação, resistência elétrica, vírus.

1. Introduction

The end of 2019 was marked by the emergence of an infectious outbreak with human-to-human transmission in the city of Wuhan, a city of more than 11 million inhabitants, the capital of Hubei province (SALES, 2020). Early on, attempts were made to find possible causes for the origin of the virus, which was identified as belonging to the Severe Acute Respiratory Syndrome (SARS) family. The SARS, it is a virus of the one of the greatest infectious severity and epidemiological potential, belonging to the Coronavirus group, which was given the sub code CoV-2 because of its great similarity to the SARS-CoV virus, the causative agent of the SARS epidemic in 2002 (LINTON, 2020). Nevertheless, according to (CHEKE 2020), Coronavirus was first observed in 1930, and the first Coronavirus in humans in 1960. The clinical complications caused by SARS-CoV-2 (the disease caused by the New Coronavirus, which became commonly known as "COVID-19", which stands for "Coronavirus Disease 2019") develop in the host's body a circuit of lesions that, in many cases, become fatal, namely, when they affect certain risk groups such as older populations and/or those with comorbidities (DIXIT e PANDA, 2021)

Most people become infected with common coronaviruses throughout their lives, with young children more likely to become infected with the most common type of the virus. The most common coronaviruses that infect humans are alpha coronavirus 229E and NL63 and beta coronavirus OC43, HKU1 (KSIAZEK et al, 2003). Covid-19 disease is spread through the air by micro droplets, mainly when they are expelled by infected people when they cough or sneeze, which can "travel" for meters before falling to the ground (some studies say up to 4.5 meters) (ALLAMAN e JELIHOVSCHI, 2022). Studies have shown that the higher the humidity, the greater are the chances of these micro droplets colliding with other micro droplets of water, present in the air, thus becoming heavier and falling to the ground faster (MIGUEL e BABAK, 2020; CHAN, 2011; PRUSSIM, 2018; WAYMER, 2020). Obviously, this decreases the probability of spreading the disease through the air, which is one of the most important modes of dissemination (FRICHI et al, 2022).

Studies show that the virus particles can remain in the air as aerosols, causing them to spread more quickly (WAYMER, 2020). Aerosol transmission occurs when several respiratory droplets produce microscopic aerosols by evaporation, when a person breathes and coughs and sneezes or speaks. Aerosols contain enough virus to cause infection, and active virus has been detected in aerosols at a distance of 2 to 4.8 m from sick patients (MIGUEL e BABAK, 2020).

Aerosols are tiny by definition, measuring on average five micrometers in diameter, and evaporation can make them even smaller. Therefore, a heated surface using a system with electrical resistance can increase this evaporation causing the destruction of the virus.

The purpose of this paper is to admit that the SARS-CoV-2 disease is spread indoors through the spread of the virus between infected and healthy people via water droplets present in the air (humidity). Thus, we investigate how an equipment with an electric resistor installed in the air-conditioning outlet is able to sterilize a room $2m \times 2m \times 2m$ meters and for how long. The sterilization will take place by contact of the droplets containing SARS-CoV-2 on the surface of the electrical resistor under a temperature of 60 degrees Celsius.

2. Methodology

The air is an efficient carrier of particles, dust and droplets and can be full of microorganisms, such as mold characterized by stains on walls indicate high amounts of fungi in the environment and favorable conditions for their development, the presence of these organisms can cause or aggravate several diseases ranging from skin allergies to respiratory problems (BARROS, 2019). It is known that fungi is not the only type of airborne microorganism, SARS-CoV-2 can occur through the air as well, in addition to direct, indirect, or close contact with infected people through infected secretions such as saliva and respiratory secretions or their respiratory droplets, which are expelled when an infected person coughs, sneezes, speaks, or sings. Airborne transmission is by aerosols, which contain the infectious agent, caused by the dispersion of droplet nuclei (aerosols) when suspended in the air moving over long distances and time (ZHOU et al, 2021).

The methodology will follow computational mathematical modeling, which is fundamental to this study, since it simulates real systems by means of computational models and evaluates their behavior without the need to build a real system, thus avoiding high costs.

Modeling is representing a real physical system, or part of it, in symbolic form, conveniently prepared to predict or describe the behavior at any future time. Models can be classified into four types, namely: Iconic, Diagrammatic, Mathematical, and Computational. It is the last classification that interests us.

The proposed equipment that will be modeled is composed of a prismatic box containing gaps on the faces and inside a ceramic resistor, as shown in Figure 1.

Figure 1: Equipment with electrical resistance against SARS-CoV-2

We will use computational mathematical modeling to obtain information about the velocity distribution of the volume of air, containing droplets that passes through the equipment in Figure 1 and data about the temperature field that is distributed throughout the room without the Sars-Cov-2.

The mathematical method employed in the present work consists of solving the Fourier equation (1) of heat diffusion in Cartesian coordinates, for the ceramic resist Figure 2. The resist is a prism that in Cartesian coordinates is given by the equation:

$$\rho C_p \frac{\partial T}{\partial t} + \rho C_p \vec{u}.\nabla T + \nabla.\vec{q} = 0, \qquad (1)$$

and

$$\vec{q} = -k\nabla T \qquad (2)$$

where: C_p Specific heat capacity at constant pressure J/(kg·K), $\vec{q}$ Conductive heat flux (W/m^2), ρ kg/m^3 density, $\vec{u}$ Fluid velocity vector (m/s), T Celsius Temperature, k W/(m·K) Thermal conductivity. Figure 2 shows the resistor that generates heat.

Figure 2: Electrical Resistance

Heat transfer is thermal energy in transit, due to a difference in temperatures in space. Its study is fundamental in all branches of engineering and it plays a crucial role in applications such as the generation and transfer of energy, environmental pollution, materials treatment, thermal comfort of buildings, thermal insulation, heat dissipation in electronic components, various medical devices, among others.

Table 1: Basic computer and software configuration

Item	Specification
Processor	Intel (R) Core (TM) i3-2310M CPU @ 2.10 GHz
Memory (RAM)	4.00 GB
Operational System	Windows 7 64 bits
Software CAE	COMSOL Multiphysics 5.1
Graphic Software	Origins Pro 8
Software	Mathematica

For the computational simulation, in this work, the software used to perform the simulation is COMSOL Multiphysics. The specifications of the computer and tooling used are presented in Table 1. However, the results of this paper can be reproduced on any other equipment or software with these minimal specifications; otherwise, the software used may not work.

The program has different modules designed to simulate specific physical phenomena, such as heat transfer, fluid dynamics, structural mechanics, chemical reactions, and electromagnetism. When adding a module to the simulation model, the equations that mathematically model the physical phenomenon (usually partial differential equations) are loaded by default, without the user having to determine them manually. However, if necessary, the user can change any equation to fit his model to the phenomenon that is intended to be simulated.

In the present study, the simulation model chosen is the "model wizard", consisting of an intelligent module, which facilitates the construction of the model. The dimension of space worked was in three dimensions. The physical method used to solve the problem was the heat transfer "Heat transfer module", this module allows analyzing heating and cooling effects in different systems. It also offers simulation tools to study heat transfer mechanisms - conduction, convection, and radiation - usually associated with other physical methods. Thus, the Heat Transfer Module enables the study of situations where there is generation, absorption, or transfer of heat or energy, having wide application in industry and science communities. The type of study in the problem was "Time Dependent", that is, in which the time dependence is not stationary, since the heat inside the kernel varies with time. Figure 3 presents the summary of the steps mentioned for the preparation of the simulation environment.

Figure 3: Programming Steps

After preparing the simulation environment, the geometry is built, for representation in parallelepiped form using the tetrahedral mesh, with the block option. The program has an extensive materials library, containing data on more than 2,500 materials, including elements, minerals, metallic alloys, thermal insulators, semiconductors and piezoelectric materials, each material has properties represented by functions, for up to 24 properties.

After defining the geometry and the material, the calculation mesh is created. The mesh chosen for the model simulation consists of a tetrahedral, fine mesh type with automatic construction. Automatic and semi-automatic meshing tools are available in the program, including free tetrahedral mesh creation and swept mesh creation. The default algorithm is automatic tetrahedral mesh creation for physical methods defined in solids and a combination of tetrahedral and boundary layer mesh creation for fluids. One can also engineer a custom mesh by defining the mesh sequence; this allows a combination of different tetrahedral, prismatic or hexahedral elements and can be parametrically oriented. The program also supports pyramid elements, on meshes imported from the NASTRAN SOFTWARE; this can be successively partitioned on the domain, boundary and edge levels with respect to coordinates, by means of extra operations.

The program allows you to separate the different finite element geometries (in 3D: tetrahedron, prism, hexahedron, pyramid) from "finite element shape functions". Consequently, it offers great flexibility, and the geometries support first, second, and third order functions, and in some situations support higher orders. In heat transfer Lagrange finite elements are widely used. In addition, it is called isoperimetric nodal based finite elements. There are different types and sizes of meshes, the more refined the more accurate is the simulation and consequently the higher the computational effort. The calculation meshes are essential for performing the simulation, because from them, the partial differential equations are solved by means of the finite element method, a mathematical method that is based on the subdivision of infinitesimal parts of the continuous medium into elements that maintain the properties of those who originated them. In this way, the elements generated with the discretization are described by means of differential equations, as well as solved by mathematical models. Thus, providing the simulation results.

The physics involved in this simulation involves three mechanisms for heat transfer: radiation, conduction, and convection. In conduction heat, transfer occurs within a substance or between substances that are in direct physical contact. Convection only occurs in liquids and gases, i.e., heat transfer occurs within a fluid through movement of the fluid itself. Radiation transfer is disregarded in the computer simulation in this work.

The system consisting of electrical resistance Figure 1 is added to the air outlet of the indoor air conditioning system to the enclosed room Figure 4. The electrical resistance has the dimensions given approximately as seen in Figure 5. The flow of convection current from the air conditioner is indicated by the red arrow acting perpendicular to area A of the electrical resistance, Figure 5.

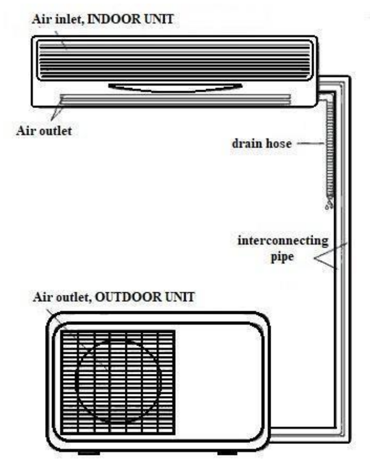

Figure 4: Cooling System

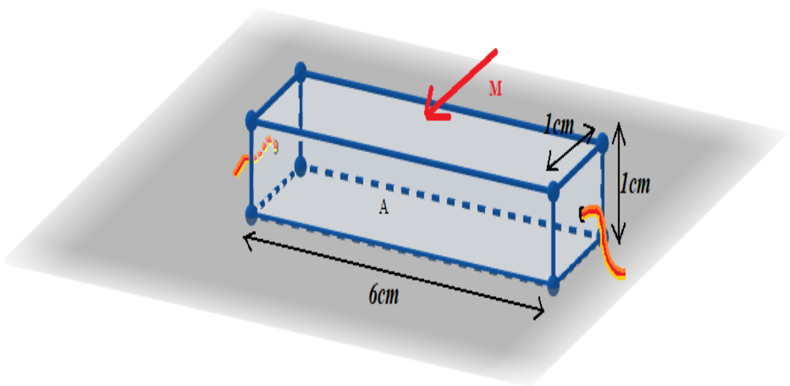

Figure 5: Schematic drawing of the electrical resistance under the action of the air flow

Air conditioning flow data are average velocity between 0.05 and 0.40 m/s and turbulence intensity less than 70% with a temperature of 16^{0}C (CANDIDO et al, 2010). Table 2 presents the electric resistor data and Table 3 the composition of the equipment in Figure 1.

Table 2: Electric resistor data

RESISTOR CHARACTERISTICS	
Composition	Aluminum Alloy
Resistance	10^{14} to 10^{10} **Ω**
Density	3.75 to 3.95 g/cm^3
Power	5W
Thermal conductivity	30W/mK
Heat capacity	775 j/kgK
Minimum operating temperature	-55°C
Maximum operating temperature	+ 230°C

This work is based on an analysis via computer simulation between the values defined as air velocity by the standards ASHRAE 55 e ISO 7730 (CANDIDO et al, 2010; FERNANDO et al, 2021); with the results obtained in field experiments regarding the preference and acceptability of air movement. We assume that the air velocity is composed of droplets present in the moisture containing Sars-Cov-2 (LU et al, 2020; KUDO et al, 2019).

Table 3: Composition of the equipment

EQUIPMENT CHARACTERISTICS	
Length	10cm
Width	7.2cm
Depth	2.8cm
Power	5W
Maximum cabinet temperature	60°C
Voltage	127V
Reach	$10m^3$

The simulation recreates a room measuring $2m \times 2m \times 2m$ for length, width and height in meters. The room has an air conditioner that is a source of air at 16 ^{0}C and an electrical resistance at the outlet of the air conditioner.

3 - RESULTS AND DISCUSSION

As airborne transmission of SARS-CoV-2 is still being studied, the concentration of airborne contaminated particles has not been defined (ZHOU et al, 2021). However, it is known that there is enough risk to generate a probable infection, making confined environments a reasonable degree of risk (FRICHI et al, 2022). Thus, an enclosed environment with refrigeration is suitable place that favors the spread of viruses (CHAN et al, 2011). An example of contamination in closed environments are halls such as restaurants, Figure 6.

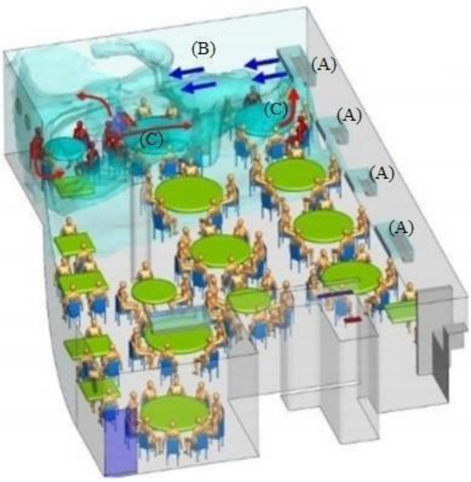

Figure 6: Restaurant with refrigerated air circulation.

In Figure 6 we have the air conditioners (A) exchanging the cooled air (B) with the heated air (C) in the room. For the computer simulation we admit a room with measurements $2m \times 2m \times 2m$ (A), air conditioner (B) and the resistor (B), Figure 7.

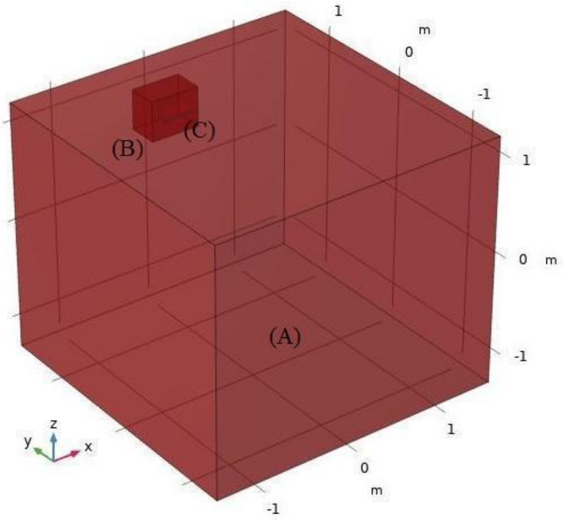

Figure 7: Simulated Room

As we can see in Figure 7, the geometry considered for the computational simulation of the systems (room-air-resistance) was simplified, that is, details of the room, the air conditioning equipment, and the electrical resistance were removed, thus reducing the computational effort.

The analysis of the results begins with the geometric definition of the room, Figure 7, already defined previously, by the use of a CAD/CAE tool, the discretization of the related domains, Figure 8 A and B, as well as the simulations for estimating the temperature field in the system using the Finite Element Method.

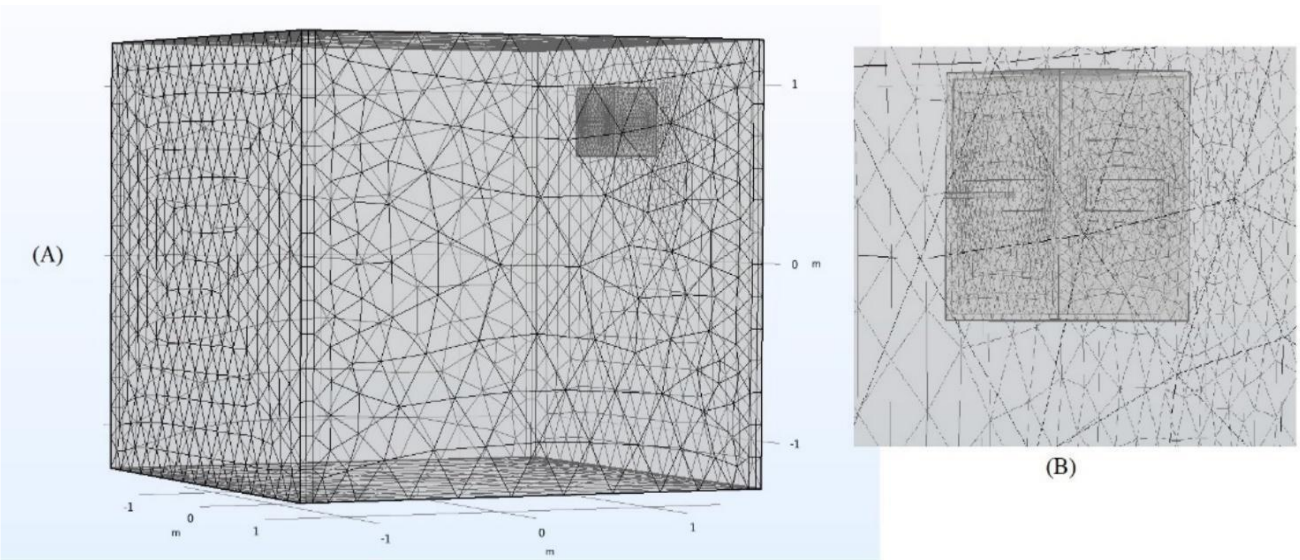

Figure 8: Discretized mesh A room and B air-resistance

Figure 9 shows the velocity field obtained by the room-air-resistance system for 1h, 5h, 15, and 24 h. We can observe that the airflow with a velocity of 0.2 m/s and a temperature of 16 ^{0}C is acting on the resistance and spreading the air throughout the room. Notice that after a certain distance the velocity drops to below 0.05 m/s. The images in Figure 9 show that the sterile air moves throughout the room for 1 to 24 hours with air conditioning running for 1 day.

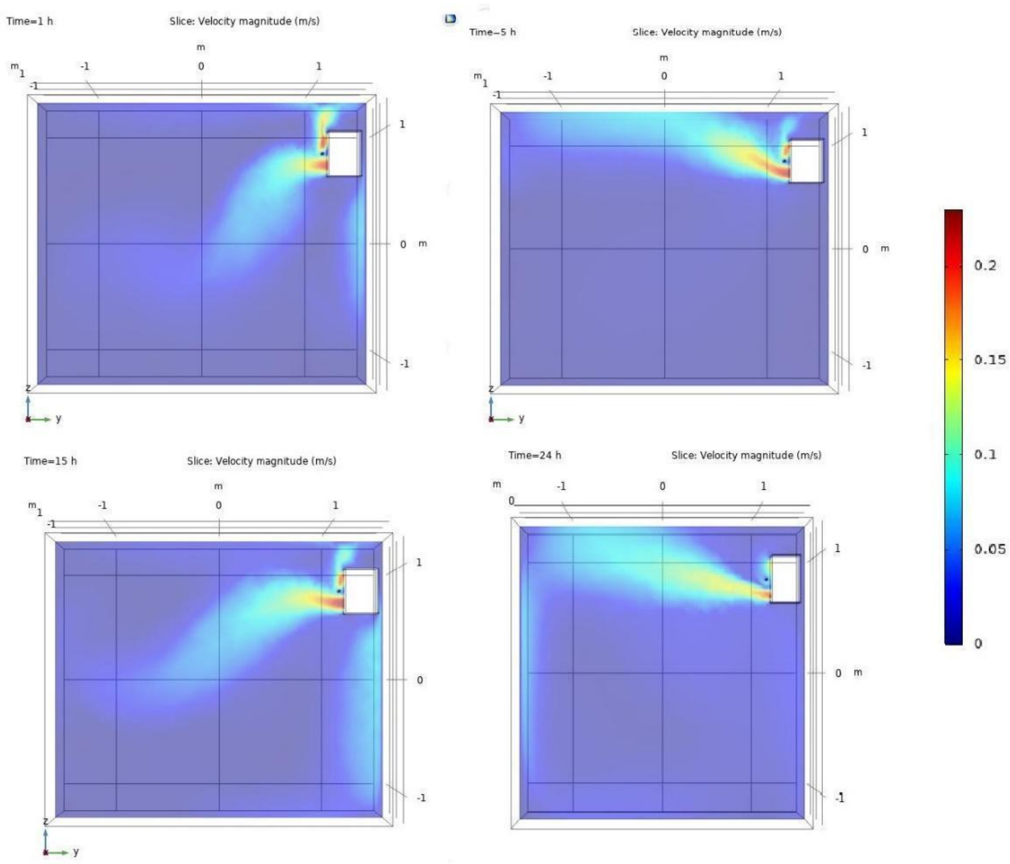

Figure 9: Velocity field in the room

When the airflow with velocity of 0.2 m/s at 16 ^{0}C reaches the electric resistor, we have a local temperature distribution as shown by Figure 9 with cut parallel to the XY plane. It is observed that at the resistor we have a temperature of 60 ^{0}C and that it drops with distance, Figure 10. The simulation shows that up to 0.05 m from the electric resistor the temperature drops to around 45 ^{0}C in the Y direction of the room. This shows that the temperature variation is localized near the resistor. Therefore, there is no impact on the room temperature.

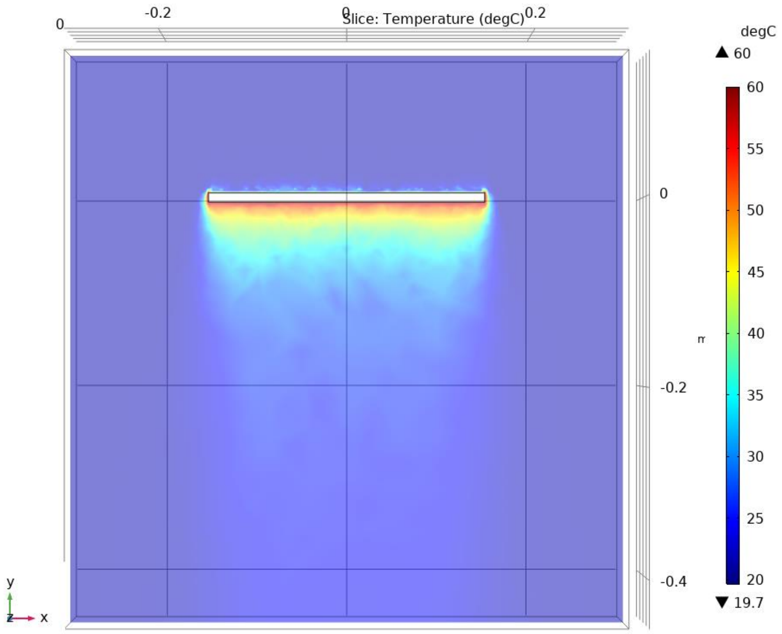

Figure 10: Airflow under electrical resistance

4 - CONCLUSION

In Wuhan, capital of Hubei Province in China, in late 2019, an outbreak of severe acute respiratory syndrome with high transmissibility was detected (A new viral strain of Coronavirus, named SARS-CoV-2, Severe Acute Respiratory Syndrome coronavirus, (ALLAMAN e JELIHOVSCHI, 2022), responsible for the disease named COVID-19, was identified through laboratory techniques.

Due to the presence of SARS-CoV-2, a respiratory disease with airborne transmission, air-conditioned environments that do not have an adequate air renewal and treatment system become risk factors, and can contribute to the increased transmission of this disease.

Since closed spaces are simply not suitable for this new reality - the facing a pandemic of severe acute respiratory illness with airborne transmission as well - it became necessary to ensure that air conditioning systems have filters to contain COVID 19 contamination.

The pandemic caused by the SARS-CoV-2 virus and the transmission of the virus by air carries with it the need to review the practices and infrastructures of air conditioning. This text has tried to list the main points to support the discussion of the problems and possible solutions. However, it is not exhaustive, new information can drastically change the whole picture.

The proposal presented here is to contain the spread of COVID 19 (SARS-CoV-2) via electrical resistance used at the outlet of the air conditioning equipment. The simulation shows that this technique is promising, because after the interaction of the droplets, containing SARS-CoV-2, with the electrical resistance we observe that the whole room receives decontaminated air for 24 hours.

However, one thing is certain! The control of indoor air quality through renovation, which is obtained by filtering the air, has become a major concern and very important due to the control of temperature and humidity of the air indoors, considering also that there are besides COVID-19 other contagious diseases transmissible by aerosol or suspended particles, some even more lethal.

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