Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 3266 – 3273
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.4967

Room Air Purification through the "Silent Virus Killer"

Khaled R. Asfar[1], Saifeddin M. Sawan[2]

Abstract

A "Silent Virus Killer" is proposed for room air purification/sanitization. This unit is primarily an indoor space heater in winter time in many homes around the world as kerosene or gas heaters. The proposed outcome of these heaters, in addition to warming room air with high thermal efficiency, is thought to annihilate airborne viruses, bacteria, and living organisms inside rooms, classrooms, or businesses. These airborne micro-organisms are completely eliminated by incineration when the air carrying these tiny creatures passes through the high-temperature glowing dome space heaters. Kerosene and LPG gas burn at temperatures above 900o C. No living organisms can survive these temperatures. The Corona virus and all other viruses cannot survive temperatures above 70oC. The driving force that moves the heated air upwards above the heater and draws cold air from below the heater is due to buoyancy. Rising hot air column cools down when it mixes with the room colder air and eventually impinges the much colder ceiling. Consequently, it diverges radially outward from the point of impingement with the ceiling and goes down towards the floor. The current study consists of two parts; Numerical simulation of the flow field due to this phenomenon as well as an experimental part which measures temperature and velocity distribution in the rising hot air column. The numerical simulation is carried out using the XFLOW Code. Several combustion temperatures are assumed at the outlet of the glowing dome in the heater ranging from 600-900 degrees Celsius. Temperatures and rising hot air column upward velocities are obtained. The experimental part is also carried out on a kerosene heater and its effect on purifying/sanitizing the room air is studied. The location of the heater in a given room size is investigated and an optimum position is determined. Room ventilation is a necessity for such heaters.

Keywords: *Air Purification, Silent Virus Killer, Room Air.*

Introduction

With the outbreak of the Covid-19 Pandemic at the end of 2019, there was strong interest in air purification to clean room air in residential areas or work space in order to reduce infections by the virus from one person to another. A recent study published in Emerging Infectious Diseases Journal showed that the virus dispersed through the air remains infectious for up to 16 hours. Such findings emphasize the need for indoor air protection [1].

Air purification devices exist commercially, however, they are intended for removing contaminants in the room air and thus improving the indoor air quality. Pollen, dust, smoke particles, and other air contaminants are largely removed by filtration and thus people with allergy and asthma are relieved. Some odors are also removed from room air. HEPA filters are used with an efficiency of capturing airborne particles reaching 99.97 percent [2] and [3]. However, their efficiency in capturing airborne viruses is in doubt, on the contrary these purifiers may do more harm than good in confined spaces [4].

However, operating air purifiers or air ventilation systems in confined spaces such as rooms in houses and classrooms while occupied by several people leads or can lead to increased airborne virus transmission due to air circulation effects [3]. Furthermore, HEPA filters need to be cleaned or replaced frequently as they become blocked by trapped particles and their efficiency drops considerably.

Thermodynamic sterilization (TSS) uses heat sterilization via a ceramic core with micro-capillaries, which are heated to 200°C. It is claimed that 99.9% of microbiological particles - bacteria, viruses, dust mite allergens, mold and fungus spores - are incinerated. The air passes through the ceramic core and is heated

[1] Department of Mechanical Engineering, Jordan University of Science and Technology, Irbid-Jordan, Email: kasfar@just.edu.jo

[2] Department of Mechanical Engineering, Jordan University of Science and Technology, Irbid-Jordan, Email: kasfar52@gmail.com

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 3266 – 3273
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.4967

by forced convection. It is then cooled using heat transfer plates and released. TSS is not a filtering technology, as it does not trap or remove particles. TSS is claimed not to emit any harmful byproducts [5].

Recently, Medistar Company developed a "Biodefense Indoor Air Protection System". This system traps and kills viruses. This HVAC filter is developed through collaboration with Texas A&M and University of Houston. The filter is based on HEPA filter technology that captures and kills the virus by heating the filter to high temperatures. The filter is encased in a fire-retardent frame and uses Ultra Violet-C light to catch and kill spores as small as 1000 nanometers. Apparently, a blower is used to drive the air inside the system. They claim that "there is not any significant heating of ambient air"! [6].

Another study investigated how airborne pollen pellets (or grains) can cause severe respiratory-related problems in humans. Given that pollen pellets can capture ribonucleic acid viruses, they showed that airborne pollen grains could transport airborne virus particles such as the airborne Coronavirus (CoV) disease (COVID-19) or others. They conducted computational multiphysics, multiscale modeling and simulations. The investigation concerns a prototype problem comprising the transport of 104 airborne pollen grains dropped from a mature willow tree at a wind speed of 4km/h. They showed how pollen grains can increase the Coronavirus transmission rate in a group of people, including some infected persons. They concluded that the social distance of 2 m does not hold as a health safety measure for an outdoor crowd [7].

The current Covid-19 pandemic (2020- present), whether in its original form or its variants, is attracting research focusing on reducing infections between people who are inside homes, schools, businesses,…etc. In winter time, these indoor facilities are potential infection hazards due to low ventilation and congestion of people. The proposed indoor air purification/sanitization by kerosene/gas heaters, which are used in many homes in Jordan and the region, will sterilize the indoor environment and incinerate all types of airborne viruses (including Covid-19), germs, and bacteria provided they are located in such a way to cover the whole airspace in the room and of course with proper fresh air ventilation. Thus, purification of indoor air is achieved as a byproduct of using these units primarily intended for indoor heating purposes without any additional cost.

Description of the Device

As shown in Figure 1, The kerosene heater is a cylindrical round structure with the fuel tank at the bottom. The gauze carries liquid kerosene by capillary action from the tank to the combustion chamber which is located above the fuel tank and into the flame compartment. A wire frame surrounds the combustion chamber with a diameter of 30cm. The gauze is circular in shape and goes inside the wire mesh. A round plate cover rests on top of the wire frame. The fire compartment has a cylindrical fine wire mesh of 15cm diameter at the base and is partially covered by a small size plate of 12cm diameter at the top. This wire mesh becomes red hot when the gauze is ignited and reaches a steady state. The heating power of the device is controlled by raising or lowering the gauze. In order to facilitate rising hot air temperature measurements, the kerosene heater outer wire cage is surrounded by a 1-mm steel sheet duct with a height of 45cm. This steel sheet can be moved up and down at will. Thus the rising hot air is confined and guided by this cylindrical shell which will enable us to measure the upward velocity of the hot air. Cold air enters to the kerosene heater radially inward from the bottom of the heater and up to the heating zone.

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 3266 – 3273
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.4967

(a) (b)

Fig. 1. The Kerosene Heater in Operation (A), and the Covered Heater in (B).

Methodology

In this work simulation of the flow through a space heater that uses kerosene is carried out. Numerical experiments are performed using XFLOW to obtain some data on temperature distribution and rising hot air velocity. Different Fire dome temperatures are assumed due to several fuel burning rates (700-1220 degrees Kelvin). These high temperatures generate upward flow of air passing through the fire dome due to buoyancy.

Some live experiments are carried out to measure an average upward velocity of the rising hot air using a turbine wheel velocimeter. Also, a flow visualization technique is used (smoke) to obtain an estimate of the flow upward velocity to be used later in calculations. Consequently, the flow rate of air through the heater is calculated as follows:

Air Flow Rate through the heater (in m^3/sec) = V_{air} x A ,

where V_{air} is the average velocity of the rising hot air in (m/sec), and A is the surrounded duct area of the heater around the cage in (m^2). Knowing the room air volume V_{room}, one can determine the approximate time needed for the room air to pass through the heater and thus the purification process is completed:

Time required to purify the room air (in seconds) = V_{room}/V_{air}

Different rates of fuel consumption are experimented with for the kerosene gas heaters. As fuel consumption increases, the temperature and air velocity increases.

-The Numerical scheme XFLOW is used for the simulations. The heater highest temperature acts at the lower end and causes a rising column of hot air due to buoyancy in the simulation. Air flow maps will be constructed for a common room size and shape. An optimum location of the space heater for the dual purpose of heating the room and purification is determined from both experiments and simulations.

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 3266 – 3273
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.4967

Experimental Work

Temperature Measurement

Thermocouples are used to measure the average temperature of the rising air flow inside the duct at the outlet. A central point is taken as the measuring point and a data logger (TES 1384) is used to yield an average temperature of the rising air for each flow rate corresponding to a certain fuel consumption.

Fig.2. Data Logger and Thermocouples Used for Temperature Measurement

Airflow Velocity Measurements

Flow visualization was carried out by a simple smoke generator situated on top of the heater plate at its center. A high speed camera recorded few seconds of the rising hot air. The rising hot air average velocity was estimated to be more than 1.0 m/sec. The flow upwards was turbulent with vortices all over the column. A snap photo of the flow field is shown below.

Fig. 3. Flow Visualization Using Smoke

Upward air velocity (in m/sec) is measured using an EXTECH air velocity meter with a turbine wheel. This device measures instantaneous velocity as well as an averaged velocity over a certain period of time. The turbine wheel has a plastic rotor which makes it susceptible to melting if exposed to the hot air for

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 3266 – 3273
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.4967

more than 10 seconds. Thus, measurement time was limited to 4 seconds in order to protect the blades of the rotor from overheating and possibly melting. The measurement was repeated several times to make sure the averaged values are correct.

Fig.4. The Air Velocity Meter with A Turbine Wheel Used in the Study

Results and Calculations

Temperature

The rising hot air temperatures right above the red hot wire mesh were measured and listed in the table below. Average values of the temperatures are recorded. As shown in Table 1, the maximum temperature due to burning of the fuel reached 660 degrees Celsius. This temperature (and all other measured temperatures) will kill any viruses, bacteria, or pathogens instantly. Next, a lower flame temperature was obtained by reducing the height of the wick and measurements inside the rising hot air column were made to make sure that mixing will not decrease these temperatures considerably. So, the thermocouple probe was inserted along the centerline of the rising hot air column and temperatures were measured and recorded in Table 2.

Table 1. Maximum Temperature Distribution Above the Heater

Location above Fire dome (cm)	Temperature ^oC
2	660
5	605
10	565
15	505
20	465

Table 2. Temperature Distribution Above the Heater for Low Height Wick

Location above Fire dome (cm)	Temperature ^oC
2	485
5	420
10	375
15	350

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 3266 – 3273
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.4967

20	335

Airflow Velocity

The point of measurement of the rising hot air velocity using the turbine wheel was at the outlet of the steel sheet duct at its centerline. The average air velocity was measured to be 1.5 m/sec. This measurement corresponds to the case where all the wire mesh of the combustion chamber is red hot and there is no blue flame above this chamber.

Hence, since the diameter of the duct is 30cm, then the duct area is 0.0707 m^2.

Air Flow Rate through the heater (in m^3/sec) = Vair x A

= 1.5 x 0.0707

= 0.106 m^3 /sec

For a room size of 4m x 4m x 2.7m, the volume of air in the room is 43.2 m^3.

The estimated time to purify the room air = (43.2/0.106)/60 = 6.8 minutes

This approximate value is calculated based on the assumption that only the air inside the room is being circulated through the heater. However, it should be noted that ventilation is a necessary action with such indoor heating units which will provide fresh air to continue combustion and burning of fuel in the heater. Also, a corresponding amount of exhaust (combustion products) should leave the room to the outside. The fresh air will mix with the room air which is partly purified and this mixing will increase the time required for purification. But, at any rate, the concentration of viruses, bacteria, and pathogens will be mitigated considerably until the whole room air is purified. Hence the time required to purify the room is somewhat higher than the above calculated value.

Numerical Simulation

Numerical Simulation of the silent virus killer is carried out using the XFLOW Code. The various parameters introduced in the program are shown in the figure below. The same room dimensions were used as before. Several combustion temperatures are assumed at the outlet of the glowing dome in the heater ranging from 500 - 900 degrees Celsius. Temperatures and rising hot air column upward velocities are also shown.

Volume: 3, No: 8, pp. 3266 – 3273
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.4967

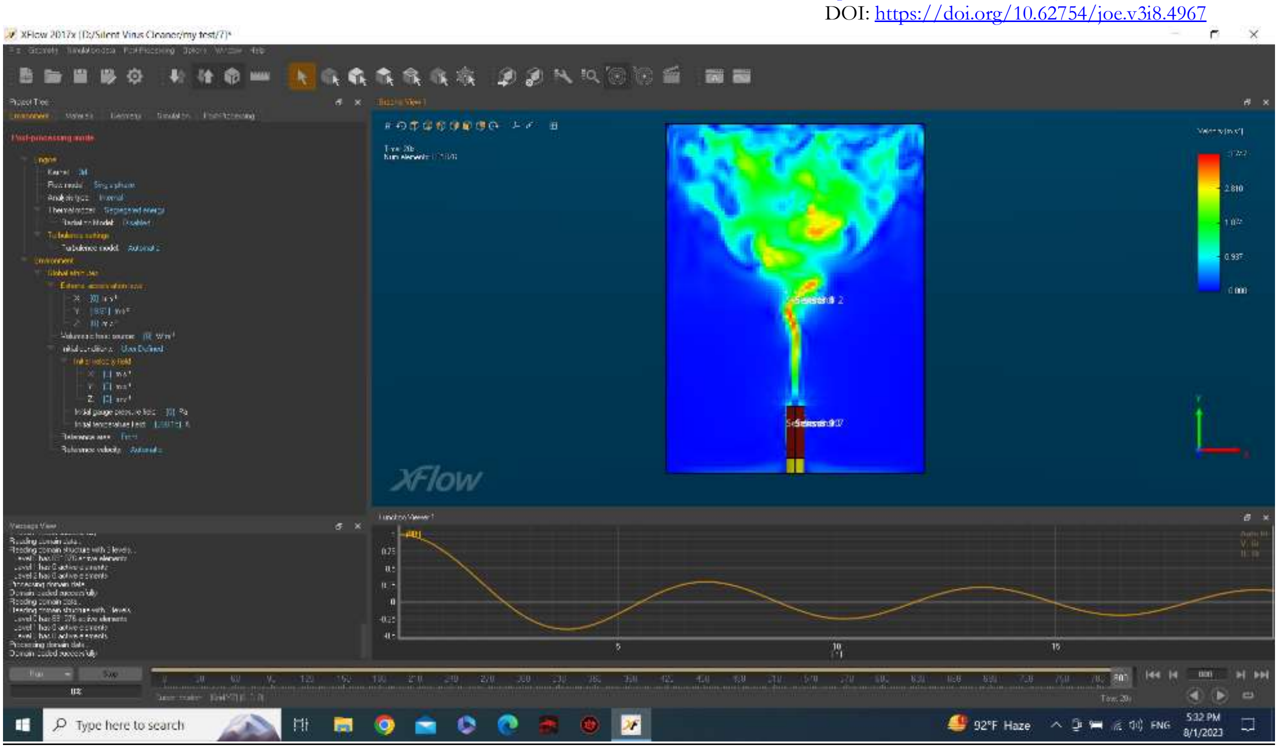

Fig. 5. Numerical Simulation Results of The Silent Virus Killer Using XFLOW Code. Velocity Profile Shown. Maximum Fire Dome Temperature: 500 ^{O} C.

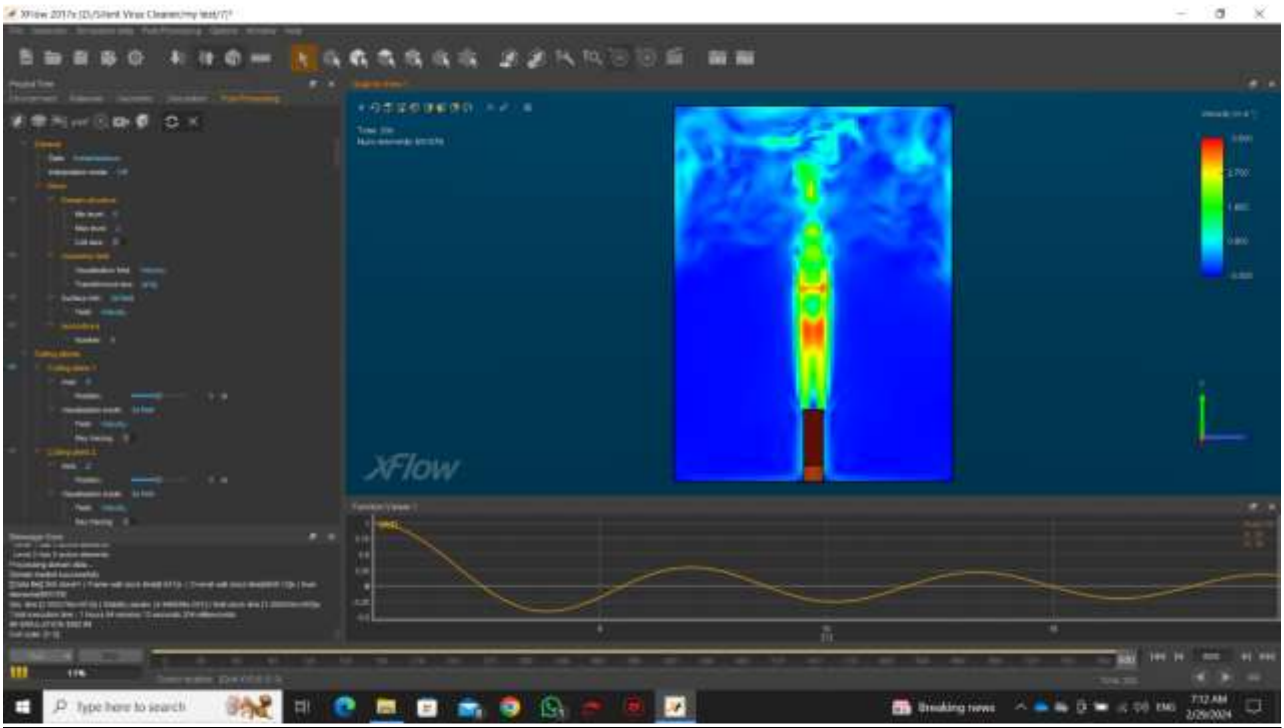

Fig. 6. Numerical Simulation Results of the Silent Virus Killer Using XFLOW Code. Velocity Profile Shown. Maximum Fire Dome Temperature: 800^{o} C.

Volume: 3, No: 8, pp. 3266 – 3273
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.4967

Concluding Remarks

In this work, it was shown that heaters of this type, although used primarily for space heating in homes in winter, are capable of killing silently all viruses, pathogens, and any living tiny creatures in the room air that pass through the combustion glowing dome with the room air as they cannot endure the very high temperatures that result from the combustion of kerosene/gaseous fuel. It was also shown by calculations that the time needed to purify room air is relatively small (less than 10 minutes for a standard 4x4x2.7 m room). Of course, ventilation is necessary in this case and the room should not be a closed room otherwise suffocation of the residents may occur. The ventilating air coming from the outside is assumed in this case to be free from any infectious pathogens. The optimum location of the heater is found to be located at the center of the room by numerical simulation. Gas heater behavior is expected to have the same pattern of the kerosene heater as both have a hemispherical glowing dome. The optimum location of such heaters would be the center of the room. This location is anticipated from the simulations carried out showing that the rising hot air gets cooled by hitting the colder ceiling and moving radially outward adjacent to the ceiling and then falling down away from the heater area. Colder air is sucked into the heater to continue the circulation pattern. Hence, the use of such heaters, in addition to their high space heating efficiency, contribute to a cleaner environment free of airborne viruses, bacteria, and living organisms inside rooms, classrooms, or businesses.

Acknowledgement

This work was supported by the Deanship of Research/JUST University under project No. 20210296 during Sabbatical leave 2022.

References

"Virus Killer", by J. Kosowatz, Mechanical Engineering, No.1, 143, January 2021.

"Types and Function of Air Filters | Air Filtration System for Home, Office and Car". Official Blog Updates - Honeywell Air Purifiers. 2017-09. Retrieved 2023-12.

"Air Cleaning Technologies". Ontario Health Technology Assessment Series.

No. 5 (17): 1–52. 2005-11. ISSN 1915-7398. PMC 3382390. PMID 23074468.

"Air purifiers may do more harm than good in confined spaces with airborne viruses". Phys.Org. Retrieved 14 January 2024.

https://www.freshairpro.com/airfree-p3000, accessed on 22/4/2021

L. Yu, G.K.Peel, F.H. Cheema, W.S. Lawrence, N. Bukreyeva, C.W. Jinks, J.E. Peel, J.W. Peterson, S. P. Aessler, M. Hourani, and Z. Ren, "Catching and killing of airborne SARS-COV-2 to control spread of COVID-19 by a heated air", Materials Today Physics, Vol. 15, December 2020, 100249.

T. Dbouk, and D. Drikakis, "On pollen and airborne virus transmission", Physics of Fluids, 33, 063313 (2021).