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Double Atomizing Nozzle-Blower Sanitizing Cabin for Safe Clinical Applications

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Abstract: *The first CONVID 19 case in Nigeria was reported on 25th February, 2020. Since then the spread of the virus has become astronomic. The spread is mainly propagated through aerosol droplets produced through breathing, coughing and sneezing. Big droplets ≥ 5 µm rapidly fall to the ground while the droplets nuclei ≤5 µm in diameter, remain suspended in air for significant periods of time, allowing them to be transmitted over distances >1 m (Atkinson et al., 2009). Any disinfection that would effectively attack the virus must necessarily be in the same droplet diameter range as the virus. The finest possible Volume Median Diameter (VMD), from conventional hydraulic energy nozzles is 60 µm; whereas diameter of common viruses including coronaviruses, range from 0.004 - 1.0 microns (Dietz et al., 2020). When requisite spray droplets sizes are produced, human sanitizing cabins or tunnels become a very effective way to prevent the spread of pathogens and infections with a walk through the cabin providing effective disinfection. It is an engineering misdemeanor that conventional hydraulic energy nozzles used for domestic, industrial and agricultural applications are employed for sensitive clinical disinfection in most conventional tunnels and cabins. They produce large droplets which fall rapidly to the ground under gravity, and on the body of the occupant; while the virus droplets remain airborne with undiminished potency. The result is ineffective disinfection as the viruses escape vitiation while the human user is put to health risks. This invention installs a blower to suck in conventional spray droplets from hydraulic energy nozzles; into turbulence with air thereby further atomize the droplets by evaporation and friction to effective sizes ≤ 5µm; before delivery into the cabin. This work presents the novel equipment capable of generating disinfectants of upper-class droplet diameters close to that of viruses. This is achieved through laboratory experimentations and tests.*

Keywords: *Covid 19, Human, Spray, Microns, Airborne*

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I. Background Of The Study

Environmental conditions within human occupied spaces in most cases contribute majorly to the comfort or otherwise of the occupier. Human comfort and health can be enhanced by the introduction of water as in humidification, and human friendly sanitizers or disinfectants when necessary. Also unseen viruses can be deactivated through sanitization and disinfecting paths and occupied spaces. But any disinfection that would effectively attack a virus must necessarily be in the same droplet diameter range as the virus.

Conventional systems shown in Plate 1 and Plate 2 use agricultural and domestic nozzles and thereby deliver chemicals in lethal dozes on individuals. Spray nozzles are classified as very fine (< 100 µm), fine (100 − 175 µm), medium (175 − 250 µm), coarse (250 − 375 µm), very coarse (375 − 450 µm), or extremely coarse (> 450 µm). (Hilz, 2013). Thus the finest possible Volume Median Diameter (VMD), from conventional hydraulic energy nozzles ≤ 100 µm; whereas diameter of common viruses, range from 0.004 - 1.0 microns (Dietz et al., 2020).

It is an engineering misdemeanor that conventional hydraulic energy nozzles used for domestic, industrial and agricultural applications are employed for sensitive clinical disinfection in most conventional tunnels and cabins. They produce large droplets which fall rapidly to the ground under gravity, and on the body of the occupant; while the virus droplets remain airborne with undiminished potency. The result is ineffective disinfection as the viruses escape vitiation while the human user is put to health risks. When requisite spray droplets sizes are produced, human sanitizing cabins or tunnels become a very effective way to prevent the spread of pathogens and infections with a walk through the cabin providing effective disinfection.

Humans produce respiratory aerosols (droplets) by several means, including breathing, talking, coughing (Figure 1). The term "droplet", as used in this context, consists mostly of water with various inclusions, depending on how it is generated. Naturally produced droplets from humans (e.g. droplets produced by breathing, talking, sneezing, coughing) include various cells types (e.g. epithelial cells and cells of the immune system), physiological electrolytes contained in mucous and saliva (e.g. Na+, K+, Cl-), as well as, potentially, various infectious agents (e.g. bacteria, fungi and viruses).

Plate 1: Conventional Disinfectant Cabin

Plate 2: Conventional Disinfectant Cabin

Both these naturally and artificially generated droplets are likely to vary in both size and content. Droplets >5 μm tend to remain trapped in the upper respiratory tract (oropharynx — nose and throat areas), whereas droplets ≤5 μm have the potential to be inhaled into the lower respiratory tract (the bronchi and alveoli in the lungs). Currently, the term droplet is often taken to refer to droplets >5 μm in diameter that fall rapidly to the ground under gravity, and therefore are transmitted only over a limited distance (e.g. ≤1 m). In contrast, the term droplet nuclei refer to droplets ≤5 μm in diameter that can remain suspended in air for significant periods of time, allowing them to be transmitted over distances >1 m (Atkinson *et al.,* 2009).

Figure 1: Droplets production through the mouth and nose

Disinfection is essential for ensuring that hosts do not transmit infectious pathogens to other persons. Failure to properly disinfect carries not only risk associated with breach of host barriers but also risk for person-to-person transmission, and transmission of environmental pathogens. Ethanol (78%e95%), iso-propanol (70%e100%), the combination of 45% iso-propanol with 30% n-propanol, glutardialdehyde (0.5e2.5%), formaldehyde (0.7%e1%) and povidone iodine (0.23%e7.5%) readily inactivated coronavirus infectivity by approximately 4 log10 or more. Sodium hypochlorite required a concentration of at least 0.21% to be effective. Hydrogen peroxide was effective with a concentration of 0.5% and an exposure time of 1 min. Data obtained with benzalkonium chloride at reasonable contact times were conflicting. Within 10 min a concentration of 0.2% revealed no efficacy against coronavirus whereas a concentration of 0.05% was more effective. In contrast, 0.02% chlorhexidine digluconate was basically ineffective (Kampf, 2020).

A spray is often characterized by its volume mean droplet diameter (VMD or Dv50). The VMD is the midpoint droplet size, where half of the volume of spray is constituted of smaller droplets, and half of the volume is constituted of larger droplets. American Society of Agricultural Engineers classified agricultural spray according to the VMD as: very fine (≤100 µm), fine (100-175 µm), medium (175250 µm), coarse (250-375 µm), very coarse (375-450 µm), or extremely coarse (≥450 µm) (De Cock, 2017). This is collaborated by Hilz, (2013) which reports that spray nozzles are classified as very fine (< 100 µm), fine (100 − 175 µm), medium (175 − 250 µm), coarse (250 − 375 µm), very coarse (375 − 450 µm), or extremely coarse (> 450 µm). (Hilz, 2013). Thus, a nozzle of 100 µm VMD has fifty percent of its droplets above 100 µm and fifty percent below 100 µm. The problem with conventional spraying practice to combat virus pandemic is the employment of agricultural nozzles and sprays; the droplets of which are about ≤100 µm to attack viruses which droplets range from 0.004 - 1.0 microns (Dietz et al., 2020). Agricultural spray nozzles produce a wide range of spray droplet sizes - from10 to more than 1000 microns. As a comparison, a pencil lead is approximately 2000 microns in diameter. A paper clip wire is 850 microns, a staple wire is 420 microns, a toothbrush bristle is 300 microns, a sewing thread is 150 microns, and a human hair is approximately 100 microns in diameter (Crop Watch, 2006). The volume and surface area of a spray droplet of a given diameter is given as:

$$V = \frac{1}{6}\pi D^3$$ ……… (Fritz, 2018) ------ (1)

$$A = 4\pi r^2$$ …….. (Triwahyuningtyas and Suastika, 2019) ------ (2)

The speed at which a droplet falls when released into still air, called the sedimentation velocity, is strongly related to its diameter. Studies show that droplet velocity at formation is dependent on droplet diameter and that droplet velocities are fairly constant for the different droplet sizes down to a droplet size of about 70 µm. For these droplets, velocities of about 16 to 18 m s-1 were measured depending on the nozzle type. Below 70 µm, droplet velocities consistently decreased with the decrease in droplet size, down to velocities of 10 to 12 m s-1 for the smallest droplets (Nuyttens et al., 2009). As it is droplets from conventional hydraulic nozzles will quickly fall to the surface and the ground being unable to attack the virus as the finest possible Volume Median Diameter (VMD), from conventional hydraulic energy nozzles ≤ 100 µm; whereas diameter of common viruses, range from 0.004 - 1.0 microns (Dietz et al., 2020). The large droplets inhaled and deposited on human body are severely unsafe.

II. Statement Of Problem

The spread of CONVID 19 is of global concern as it negatively affects social and economic sectors. Moreover, the spread of the virus and consequent loss of lives has been astronomic. Nigeria government is looking for ways of mitigating the spread of the virus within its walls. Conventional disinfectant tunnels and cabins employ common nozzles meant for agricultural and domestic applications whose finest droplets are of Volume Median diameter (VMD) ≥ 60 µm; too large to attack CONVID 19 virus whose VMD is about 1 µm (Dietz et al., 2020); and which occasioned the warning by WHO against the use of such tunnels. These tunnels and cabins are ineffective for curbing the spread of the virus underscoring the need for a clinical disinfectant cabin with droplets capable of mixing with and attacking the virus.

This invention installs a blower to suck in conventional spray droplets from hydraulic energy nozzles; into turbulence with air thereby further atomize the droplets by evaporation and friction to effective sizes ≤ 5µm; before delivery into the cabin. This work presents the novel equipment capable of generating disinfectants of upper-class droplet diameters close to that of viruses. This is achieved through laboratory experimentations and tests.

III. Aim

The aim of this project is to design and develop clinically safe and effective disinfectant cabin capable of producing requisite size of droplets to vitiate the virus.

IV. Objectives

i. To design a clinically safe disinfectant cabin, generating spray droplets in the range of the size of the viruses.
ii. To fabricate the machine using locally available materials.
iii. To evaluate the machine to ensure chemical concentrations below inhaling and dermal lethal levels.

V. Methodology

Droplet Volume and Surface Area: As the size of most viruses, including coronaviruses, range from 0.004 - 1.0 microns (Dietz et al., 2020); the design approach is directed towards achieving spray droplet sizes close to this range to effectively combat the virus. The finest VMD of droplet from conventional nozzles given as 100 µm is employed to determine the chemical volume and surface area of the droplet. Similarly, maximum droplet diameter of the virus (1 µm) is also used to evaluate the volume and surface area coverage for necessary comparisons.

(a). Conventional droplet:

From equation (1): $V = 1/6 \times \pi \times 100^3$
$= 523{,}809.5\ \mu m^3$

From equation (2): $4 \times \pi \times (D/2)^2$
$= 31{,}428.6\ \mu m^2$

(b). Virus

From equation (1): $V = 1/6 \times \pi \times 1^3$
$= 0.52\ \mu m^3$

From equation (2): $4 \times \pi \times (D/2)^2$
$= 3.143\ \mu m^2$

Computation shows that from one individual volume of the conventional droplet about one million seven thousand (523,809.5/0.52) = 1,007,326), virus sized droplets can be produced; capable of covering 3,166,025 μm^2 surface area which is six times the area covered by the individual conventional droplet. The indication is that apart from effectiveness of application, far less volume of chemical would be discharged. Hence clinically permissible contact can be achieved alongside the gains from excess chemical saved. Action rests on sourcing nozzles that can deliver the required sprays droplets.

VI. Model Inference

Following atomization, droplets must travel through the atmosphere to arrive at their target. Two forces act to alter droplet sizes arriving at the plant surface: evaporation and friction with the atmosphere. Evaporation changes the droplet size, and for any evaporation rate, the change will be greater in smaller droplets than in larger droplets as the smaller droplets will get smaller more quickly than will the larger droplets. In some cases, the aqueous component may completely evaporate, leaving only non-volatile formulation components. Friction with the atmosphere is important because smaller droplets loose velocity more quickly than larger droplets and the terminal velocity of smaller droplets is much lower than for larger droplets. (Capinera, 2008).

IDEFICS is a random-walk model developed to describe downwind spray deposits from a conventional boom sprayer for chemical crop protection in agriculture and depicts that spray drops in air will lose their water content rather rapidly. Subsequently the remaining water free particle will evaporate very slowly with respect to the evaporation of water. it can be inferred that only water and other fluids would evaporate during application and all solutes would be chemically inert. This seems reasonable for short distance downwind drift (down to typically 10-20 m from the edge of the crop). A water drop falling through air, or floating in air, is subject to evaporation and will decrease in size. During a certain (but relatively short) transient time, the drop cools down due to evaporation, until it reaches its 'wet-bulb' temperature. At the same time, a thin layer of saturated vapour has formed around the drop. Since the temperature of the drop is lower than that of the ambient air, heat flows towards the drop and 'feeds' the evaporation process. (Holterman, 2003). When spray droplets of larger microns are introduced into an artificial forceful air stream; IDEFICS model predicts that evaporation and friction would be very intensive (more vigorous that ambient conditions), leading to droplets reduction to superfine sizes in the range of VMD of virus and thereby become airborne

VII. Equipment Description

Figure 1 shows the kernel of the invention where atmospheric air passes through a filter into a spray stream of disinfectant. Both the air and spray droplets from hydraulic energy nozzles are mixed and taken in by the blower. Further atomization and mixing are achieved as the air-spray mix is propelled by the blower and discharged as very fine clinically friendly disinfectant droplets. Isometric view of the Disinfectant Walk-through chamber is shown in figure2; while figure 3 and 4 depict the orthographic and exploded views of the invention. Succinctly, the innovation comprises a hydraulic pump that delivers fluid (water in the case of humidification and disinfectant in the case of clinical sanitization); to hydraulic energy nozzles mounted on top of a Spray Atomization Chamber. Hydraulic Energy nozzles atomizes the fluid into fine particles with droplet diameter in the range of 5µm - 100µm in the Spray Atomization Chamber before a centrifugal blower sucks the atomized fluid from the Spray Atomization Chamber and propels it in the turbulence of the blower to further disintegrate the atomized droplets to finer airborne particles with droplet diameter in the range of 0.1 – 1 µm to become airborne and mix with virus particles in the air. An Underpass is provided as a cabin which receives the air from the blower as humans pass through to become disinfected. A room replaces the Underpass when the mechanism is employed for humidification.

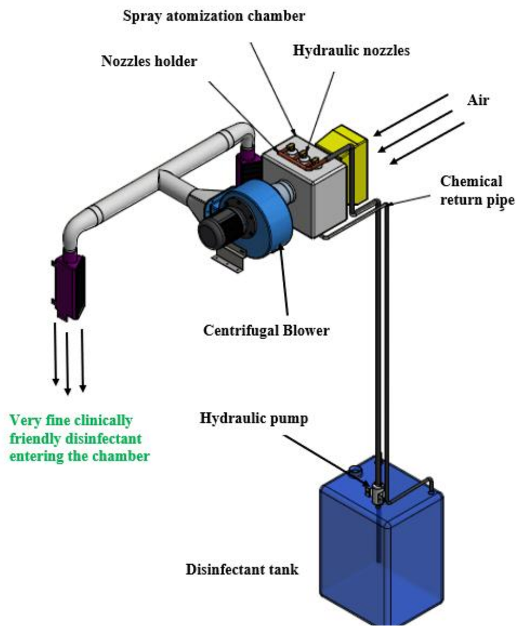

Figure 1: Nozzle-Blower atomization system of the novel Disinfectant Underpass

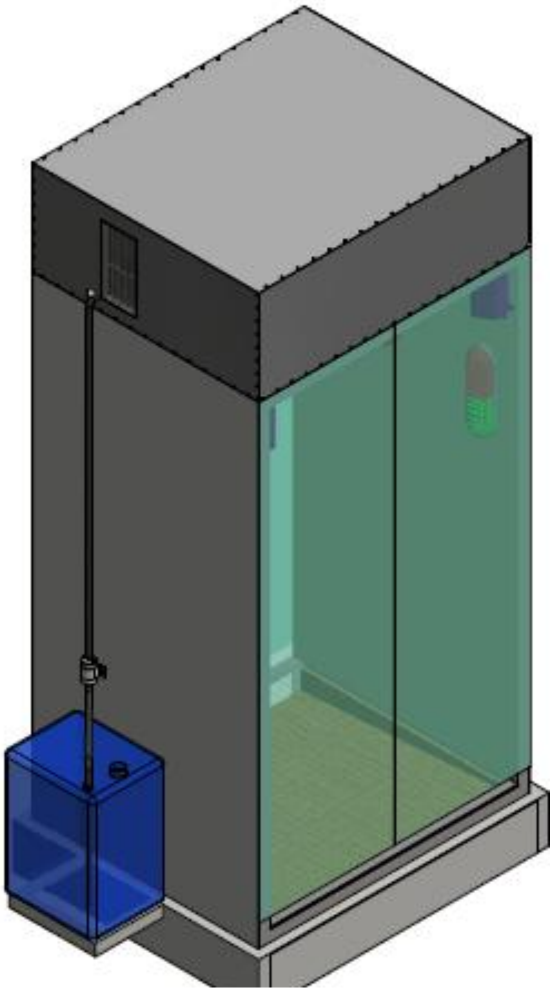

Figure 2: Isometric view of the Disinfectant Underpass

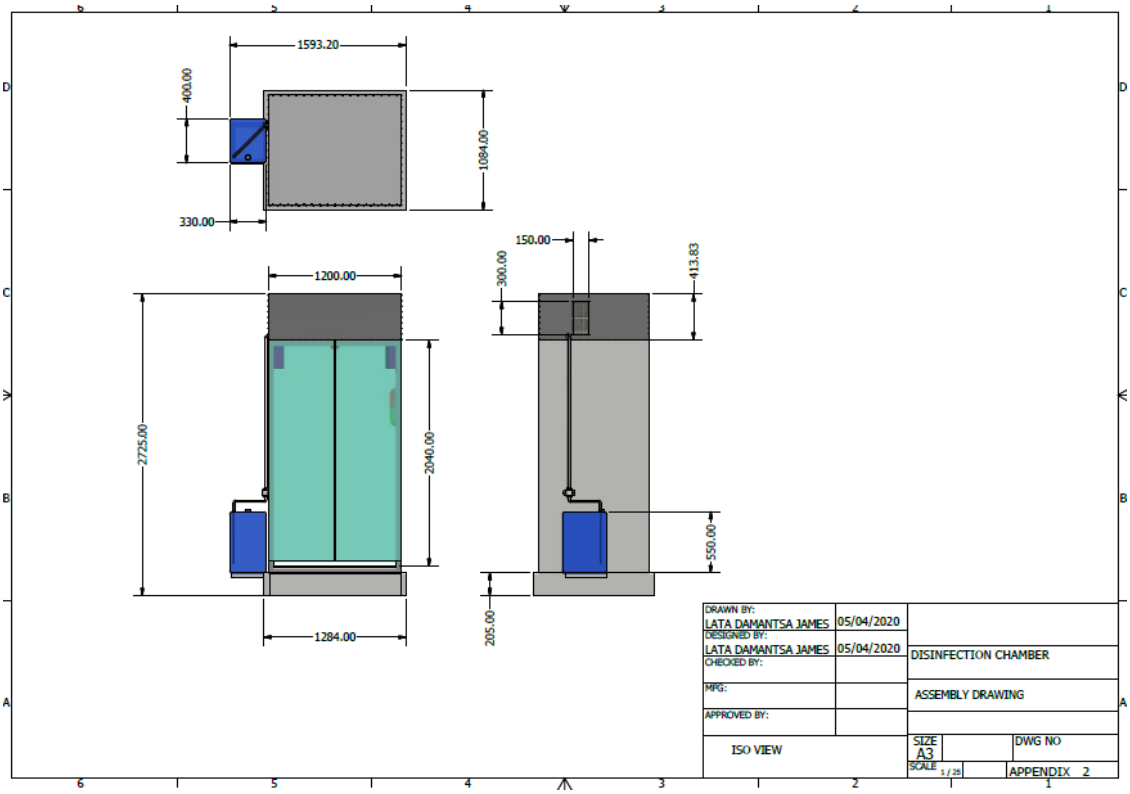

Figure 3: Orthographic view of the Disinfectant Underpass

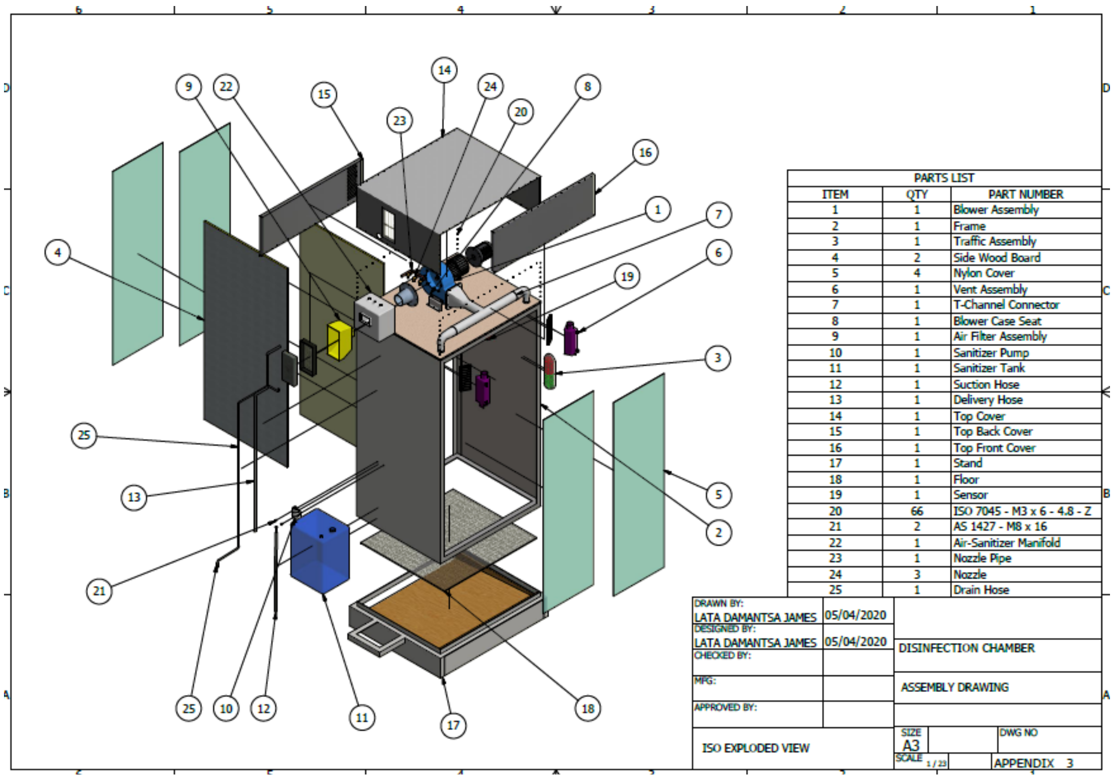

Figure 4: Isometric view of the Disinfectant Underpass

VIII. Conclusion

The introduction of this innovation is laudable especially in this era of Covid 19 and viruses. It achieves safe level for human disinfection and reduces the messy and uncomfortable experience of conventional sanitizing cabins. The innovation was achieved through the collaboration of the National Board for Technology Incubation (NBTI) and the Hydraulic Equipment Development Institute, Kano with inputs from Agricultural and Bio-Resources Department, Ahmadu Bello University, Zaria and Products and Processes Ltd., 52/53 Stadium Quarters, Kwali, FCT. It was patented in Nigeria in 2020.

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