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# Decontamination of Masks N95/PFF2 by Ultraviolet Shortwave Radiation (UV-C)

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**Abstract**

*The use of personal protective equipment (PPE) and collective protection equipment (EPC) increased exponentially with the emergence of the pandemic in 2019, briefly creating a shortage. In this sense, its use has become mandatory for medical personnel to avoid contamination and dissemination of COVID-19 to protect against the contamination of bacteria and viruses present in the environment. This article presents a UV-C disinfection booth for N95/PFF2 masks. This was used for decontamination of N95/PFF2 masks by shortwave ultraviolet irradiation was developed and evaluated with the dose of UV-C radiation reached at different time intervals, utilizinga commercial radiometer and colorimetric dosimeters. The dose of 1J/cm², indicated by the CDC for decontamination of N95 masks, was reached in 2 (two) minutes. The dose of 1.5J/cm², indicated by Ozog et al, 2020, was exceeded at 4 (four) minutes. At the interval of 1 minute and 30 seconds, the colorimetric dosimeter staining change was indicative of the optimal dose range for inactivation of methicillin-resistant Staphylococcus aureus (ARMAS) and Spore-spore-building Clostridium difficile. The decontamination proposed in the UV-c cabin for an approximate time of 10 (ten) minutes can contribute to biosafety in the reuse of N95/PFF2 masks.*

**Keywords:** Decontamination. Ultraviolet rays. Radiation dosimeters. Personal Protective Equipment. Respiratory Protection Devices. Biosecurity.

## 1. INTRODUCTION

The use of N95 filter respiratory protection masks, or filter semi-facial parts (PFF2), reduces the risk of occupational exposure to infectious aerosols[1,2]. Although usually indicated for single use, the reuse of these masks is imposed during crises in public health, given the high demand, which generates their scarcity in the market[3]. Despite the crises caused by deaths, the reuse of N95 masks is a common practice for saving resources. A study conducted in a hospital in Brazil followed this reuse by health professionals and concluded that hospitals should indicate reuse protocols and limit it to up to five days[4]. Limited reuse has been proven to not result in reduced filtration efficiency of the N95 mask[5]." The concern, however, is with microbiological safety, since there is evidence of the infectious viability of viruses deposited on its surface, which can contribute to the transmission of viruses by contact[6-11]. In light of the above, this article describes a secondary disinfection system known as a mask decontamination system that is based on the light effect produced by the ultraviolet spectrum (UV-C). Based on these premises, a simple and effective UV-C hygiene box was created as part of a mask hygiene system.

With such evidence, strategies for decontamination and reuse of N95 masks[12-16] are on the scientific agenda, with emphasis on short-wave ultraviolet light (UV-C) or Ultraviolet Germicidal Irradiation (UVGI), whose peak wavelength is 254 nm; accepted as capable of inactivating, in decreasing order of susceptibility, bacteria, viruses, fungi, and spores, through DNA and RNA damage and consequent blocking of transcription and replication, which affects microbial functions, without the risk of developing resistance and without leaving chemical residues[17-20].

The UV-C dose, which is a function of energy, area, and time, is measured in joules/cm$^2$. The total of 1J/cm$^2$ is accepted by the Centers for Disease Control and Prevention (CDC) of the United States of America as the minimum dose required for decontamination of N95 masks[1,16]. This dose (1J/cm$^2$) proved to be effective in the decontamination of masks contaminated by influenza[16]. The same dose inactivated a variety of other viruses, including influenza A (H1N1), avian influenza A virus (H5N1), influenza A (H7N9), MERS-CoV, and SARS-CoV[21]. When UV-C irradiation is applied from the outermost layer to the innermost of the N95 mask, adequate decontamination is limited and the complexity of the method is limited. It was also observed that characteristics of the mask model, such as grooves and folds, can create shadows when the piece is exposed to UV-C light and thus inhibit the efficiency of decontamination, which makes the smooth models more suitable for germicidal efficiency[22]. Research has shown the effectiveness of UV-C radiation against coronaviruses, including SARS-CoV and MERS-CoV. The dose of 3.7mJ/cm$^2$ seems to be sufficient for the inactivation of these viruses on several surfaces. These results may also apply to SARS-CoV-2 and its future mutations[23]. However, the pore nature of the N95 filter requires a higher dose, as indicated by the CDC[1, 24].

Among the urgent strategies for decontamination of N95 masks, a procedure was presented in 2020 that uses two towers with UV-C lamps positioned in opposite corners of a room in the hospital environment. Doses and 180 mJ/cm$^2$ to 1200 mJ/cm$^2$ reach the masks, depending on their positioning in the room[25]. Also in 2020, it was reported that, for decontamination of N95 masks in shell models, UV-C irradiation at a dose of 1.5J/cm$^2$, applied on both sides of the mask, is suitable for elimination of SARS-CoV-2, and elastic loops may require additional disinfection by chemical method to maximize the safety of the method[26]. It has also been demonstrated that UV-C or UVGI systems do not significantly affect the filtration performance or airflow resistance of n95 masks, although the maximum number of disinfection cycles depends on the mask model[27-29]. According to one of the largest companies producing N95 masks, UV-C decontamination systems are safe and, up to a dose of 100J/$^{cm2,}$ donot damage the equipment[30].

The possibility of a user switching the use of two or more masks can add safety to the reuse protocol since it is expected to reduce contaminants over time. In the mesh of Mask N95, a reduction of 6 log of the SARS-CoV-2 was observed in twenty-six hours, provided that the masks are stored properly[24].

This manuscript aims to focus on the issue of safety in the reuse of N95 masks, it presents a cabin option for decontamination, which is supported by the scientific certainty of the germicidal effect of UV-C radiation. Present UV-C disinfection booth for N95/PFF2 masks.

## 2. MATERIALS AND METHODS

This study consisted of a review of the scientific literature, followed by the development of a decontamination booth by UV-C irradiation and its evaluation by a commercial electronic radiometer and colorimetric dosimeters, positioned in parallel, at different distances from the UV-C light source and at different time intervals.

The developed cabin consisted of a box-type structure in MDF (medium density fiberboard), measuring 50x50x50cm, with a front opening. In the internal center of the cabin was installed the ultraviolet lamp of short wave (UV-C), a double bulb 5 cm wide, 5 cm deep, and 15 cm high, with the wavelength of 253 nm, 25 W of power, connected to the electrical network (127 V) utilizing a reactor of 20 W and a starter. The power cord of the light by the electric current was passed through a hole made in the rear of the cab and was coupled to the stopwatch to control the irradiation time.

Three features were used to evaluate the efficiency of the proposed cabin:

1) The commercial electronic radiometer, calibrated, compact, portable, 7.1 - UVC - GUVC-T10GS7.1-LA9, manufactured by Genicom Co., Ltd., with automatic data logging capabilities optimized for the 254 nm band. For the readings of the UV-C doses, the probe of the device went through a superior hole and was fixed inside the cabin through a handmade hanger, while the reader of the device was kept out of the cabin for the records of the researchers.
2) Colorimetric indicators (UV-C Dose Indicator, American Ultraviolet, Lebanon, IN). A colorimetric indicator or dosimeter positioned parallel to the electronic radiometer probe was used in each time interval tested.

With the use of these indicators, the efficiency of the process is measured based on the observation of the color change of the central circle of the card (originally yellow);

a) the change to orange indicates a sufficient dose to inactivate methicillin-resistant Staphylococcus aureus (AMS);
b) the change of color to pink indicates enough dose to inactivate Clostridium difficile spore-spore-form.

For the exposure of the N95 masks to UV-c light inside the cabin, handmade wire hangers were made, which provide the stretch of the elastic strips of the masks, to avoid bending and shadows in this material. The detail was added in colored plastic material at the base and on top of the hangers to facilitate the identification of the mask itself by the user.

Figure 1 shows the design of the cab closed and in the front opening. Figure 2 illustrates the handmade hanger of 38 cm in height and width of 10 cm, used as a support for the masks and the UV-C probe.

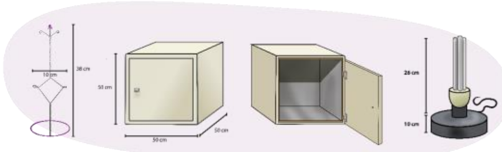


**Figure 1** – Design of the mask positioning hanger, the closed and front opening decontamination booth, and the UV-C lamp.

The internal dimensions were planned to arrange four n95 masks without overlap on a stand (Figure 2). This bracket is placed in the inside cabin and runs on a small metal guide, as a kind of centralized support between the lamp. In the mask holder, hooks were made to fix the elastics of each N95, to open and expose to UVC light the entire surface of the mask, front and back (outside and inside of the mask). Figure 2 shows an image of the interior of the cab, with the lamp and with four N95 masks positioned on the hangers.

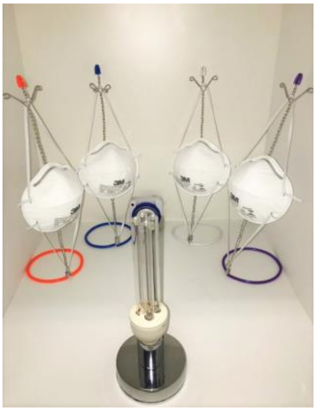

**Figure 2 -** Image of the interior of the cab with lamp and N95 masks positioned

Figure 3 shows the UV-C probe and the colorimetric indicator before exposure. For our first results were performed in irradiated dosimeters without angulation. The UVC dosimeter is a safe and efficient tool that can be used to verify UVC exposure of asurface, or an instrument, in healthcare environments, including patient rooms and surgical suites; laboratories; and food and beverage manufacturing and processing facilities.


**Figure 3 -**Uv-C probe image and colorimetric indicator before exposure

Figure 4 shows the dosimeter sensitized by UV-C irradiation in the time of 1 minute and 30 seconds.Thermoluminescentdosimeters (TLDs)are widely used in individual monitoring. In the evaluation of fading, it was observed that the relative response between dosimeters read at different time intervals presents linear variation. All care was taken by the researcher when using the UV-C disinfection booth, about the prevention of direct exposure to irradiation.

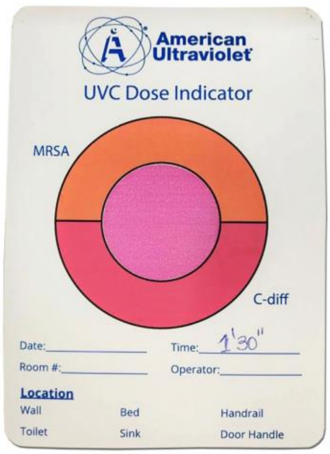


**Figure 4** - colorimetric indicator after exposure to UV-C light for 1 minute and 30 seconds at the internal limit of the cabin. Central color change, originally yellow.

## 3. RESULTS AND DISCUSSION

Figure 5 shows the graph of the variation of the UV-C irradiation dose in the disinfection booth at the interval of 1 to 15 minutes. For this determination, the radiometer probe was positioned on the handmade hanger, at the time when the mask would be, in a parallel arrangement to the UV-C light source, and at a distance of approximately 15 cm from the lamp. The UV-C dose indicated by the CDC(1) for decontamination of N95 masks, of 1J/cm$^2$, was reached at 2 minutes, while the dose indicated by Ozogand t al.[26]at 1.5J/cm$^2$, was overtaken at 4 minutes. However, the dose received by the masks may be higher, as they will be closer to the light source when positioned on the hangers for decontamination, considering the convexity of the shell.

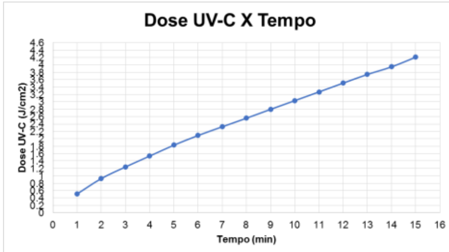


**Figure 5 -** UV-C Dose graph according to exposure time, with the radiometer probe positioned at 15cm and parallel to the lamp, affixed to a handmade mask hanger

The colorimetric dosimeters were positioned parallel to the electronic radiometer probe at the different times tested. The staining change was indicative of the optimal dose range for methicillin-resistant Staphylococcus aureus inactivation (AMS), observed at about 1 minute of exposure. The dose for inactivation of Clostridium difficile spore-spore-form was observed at the interval of 1 minute and 30 seconds.

The same treatment cycles in the UV-C booth were performed with the radiometer probe and with the colorimetric dosimeters positioned behind the mask. These tests indicated that the mask material prevents light penetration since the probe was not sensitized, as well as, there was no change in the coloration of colorimetric dosimeters.

In addition to the instructions for cabin use, the decontamination protocol resulting from this study indicated the form of storage of N95/PFF2 masks between uses. The adaptation of a commercially available food packaging by creating holes for aeration of its interior is shown in Figure 6.

**Figure 6** – Mask N95 packed in plastic packaging, in which pores were created for air passage, and adapted a cord to hang, in addition to a user identification label

Residual viruses on the surface of N95 masks are of concern in the case of reuse of this Personal Protective Equipment (PPE) by health professionals.

Therefore, mask decontamination is an important consideration to preserve biosafety in any reuse scenario[6, 7, 8, 10]. Ultraviolet irradiation of shortwave (UV-C), given its antimicrobial property, can decontaminate N95 filter masks[16,18,19,20].

In this article, the authors present a low-cost and easy-to-build option for mask decontamination, N95/PFF2, which can bring, in addition to safety in the reuse of these PPE, saving supplies, and reducing hospital waste. The booth that this article deals with can be made available in the common areas, with a well-defined protocol, including the way masks, are used and the maximum number of uses. The proposal assumes that users will use only their masks, which shouldnot have a history of direct contamination by secretions, display dirt, or present physical damage that may compromise the adjustment and function.

According to a literature review, a UV-C dose greater than or equal to 1J/cm$^2$ inactive viruses in N95masks [16], even like SARS-CoV-2. This same dose destroys Bacillus subtilis spores in N95[15] and is accepted by the U.S. Centers for Disease Control and Prevention (CDC) as the minimum necessary for the decontamination of N95masks.[1] The filtration capacity or facial seal is not altered when N95 masks are subjected to 10 or 20 cycles of exposure to this dose of UV-C radiation[22]. UV-C systems are relatively fast and easy to use, leave no chemical residues, and do not significantly affect filtration performance or airflow resistance of masks at doses up to 950 J/cm$^2$ [14,27,29].

To determine the intensity of UV-C radiation in the booth proposed inthis manuscript, a calibrated electronic radiometer capable of detecting UV radiation at the wavelength of 254nm; as well as UV-C colorimetric dosimeters were used. In the position indicated for positioning the hangers inside the proposed cabin, provided that the exposure does not have physical obstacles, the radiometer showed, in a time of 4 minutes, a dose higher than that indicated by the CDC as adequate for decontamination of N95 masks. The colorimetric indicators showed, in the time of 1 minute and 30 seconds, a change in color from yellow (untreated) to pink, which indicates sufficient dose administration to reduce C. difficile spores.

According to the results, the authors defined as safe the decontamination protocol of the Masks N95/PFF2 as 10 minutes of exposure to UV-C light in total, being 5 minutes of irradiation to each side of the mask (internal and external of the shell), which requires turning off the UV-C lamp after the first 5 minutes, opening the cabin and positioning the mask for exposure of its opposite face. The proposed protocol, according to a literature review, is also capable of disabling the COVID-19 virus. Considering two times of 5 minutes of exposure to light, interspersed with intervals to reposition the masks, plus the initial and final positioning, the approximate cycle time will be 15 minutes. Because of this, up to 4 decontamination cycles can be performed every hour. Cabin capacity is 8 to 10 masks per cycle. The dose received in different regions of the mask when exposed to light inside the cabin may be different from that determined in the tests. The most convex part of the mask shell, when turned to light, will be subjected to a slightly higher dose. However, this dose will be far below the maximum recorded in the literature, of 100J/cm$^2$[30].

Economics represents one of the principles that underpinned this research, in addition to biosecurity. Thus, sophisticated and expensive equipment, unrealistic for Brazilian public health, although efficient, was not considered a solution. In addition, the authors believe that performing or accompanying the decontamination of the mask itself would promote greater comfort to the user since the part used acquires a personal character. The indication of the packaging for storage of masks and the suggestion of alternating two or more masks, to have a greater interval between their uses, can increase the safety of the protocol, considering that the rest time of the mask in an appropriate place contributes to the inactivation of pathogens, perhaps still present in the material. The indication of limiting to 5 (five) the number of decontamination cycles of each mask is in agreement with the literature[18].

The decontamination booth presented and possible variations, such as larger dimensions, can be made available in hospitals for decontamination of Masks N95/PFF2, contributing to the better use of this protective equipment; to overcome the scarcity observed in crises, for the economics of public resources and the reduction of hospital waste. The cabin can also be used for decontamination of objects of shared use, which could represent a potential source of pathogen transmission.

## CONCLUSIONS

The UV-C disinfection booth proposes disinfection andreduction of viral load on the surface of N95 masks, reducing the risk of contamination of users. In conclusion, the UV-C booth proposed in this article, with an exposure time of 10 minutes, maybe an alternative for decontamination of N95/PFF2 masks, as part of a safety protocol for the reuse of these PPE, contributing to biosafety in health facilities.

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