COVID-19

Can a UV-C box help the cinema industry by disinfecting video cameras?

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Keywords

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Summary

Introduction. *UV-C has proven to be an effective virucide and microbicide, and its cost-effectiveness allowed it to spread as a disinfecting procedure in different environments.*
Methods. *The study aims to determine the microbicide activity on Staphylococcus aureus, Escherichia coli and SARS-CoV-2 of the UV-C Boxer by Cartoni S.p.A. Three separate experiments were performed to assess the effectiveness of the UV-C disinfection device on different materials, directly on surfaces of a video camera and on a specific carrier for SARS-CoV-2.*
Results. *In all three experiments, a significant abatement of bacterial and viral contamination was reached after 60 seconds on carriers and after 3 minutes on all examined surfaces of the video camera, with a higher reduction on glass carriers.*
Conclusions. *UV-C devices may be a valuable tool to implement in the working routine to achieve a higher level of safety in work environments.*

Introduction

In recent years, studies on the ability of microbes to colonize the environment have increased considerably, as it has been shown that surfaces can be a source of infection for humans [1]. Any inanimate object that can have infectious agents on its surface and, thus, spread them is called fomite. It has been proven how the contamination of fomites in health facilities can be a means of infection, from patients' room surfaces to healthcare workers' tools [2]. *Staphylococcus aureus*, for example, is a pathogen associated with a broad spectrum of infections both in nosocomial environments and community settings [3]. Despite it being a ubiquity that affects the skin of healthy individuals [4], it has become a relevant global health issue due to the development of antibiotic resistance. Methicillin-Resistant *S. Aureus* (MRSA) infections, in particular, are steadily growing in incidence and prevalence [4,5]. The World Health Organization (WHO) global report on Antimicrobial resistance describes how MRSA represents at least 20% of all *S. aureus* species in all WHO Regions, with some areas reporting an 80% peak [7], making MRSA a global threat and its control the main challenge for global health. Alongside Hospital-Acquired MRSA (HA-MRSA), which is an important cause of mortality in nosocomial environments [5], Community-Associated MRSA (CA-MRSA) has recently taken an essential spotlight in medical research due to its incidence among people who had no contact with healthcare environments [6]. CA-MRSA can be transmitted by direct contact between people and between shared objects and surfaces, considering that it has proven to live in surfaces for a significant amount of days [7]. This has led to fomites being essential means of MRSA infections and outbreaks [8, 9], favoring the spread of antibiocidal resistance. Gram-negative bacteria have proven to last on surfaces and fabrics in hospital environments. *Escherichia coli*, in particular, is a very common cause of HAI [10], and there's a relevant focus on this microbe due to the recent uprising of Multi-Drug Resistant (MDR) strains with the New Delhi metallo-β-lactamase - type carbapenemases [11].
In 2020 the sudden rising of the SARS-CoV-2 pandemic urged scientists to study the virus' characteristics; among them, its' transmission means. The virus, counting more than 750 million confirmed cases and almost 7 million deaths as of 22nd of March 2023 [12], is mainly transmitted via respiratory droplets and direct contact [13]; however, it is possible for the virus to contaminate high-contact surfaces and dry surfaces in hospitals [14] stratifying the risk based on virus source, time of exposure and location of the surface. In fact, Belluco et al. proposed a classification for risk of a Sars-Cov-2 infection from surfaces based on these three factors, thus dividing the risk in "High, Medium, Low and Very Low" [15]. And while as of 5th of March 2023 the WHO declared the pandemic no longer constitutes a public health emergency of international concern [16], the need to control and study the virus has led to massive restrictions, including business shutdowns that have resulted in the loss of as many as 33 million jobs worldwide and, according to the International

Labour Organisation's report, 'The most serious crisis since World War II: Job losses are increasing rapidly worldwide' [17].

To avoid these kinds of contamination, objects and surfaces disinfection is one among all precautions needed in various settings. As seen in nosocomial environments, a good disinfection practice of stethoscope is necessary to avoid MRSA contamination, but it has been reported a lax and unreliable cleaning habit from physicians and other healthcare professionals [18, 19]. New technologies, like UV light devices, have been proven effective in disinfecting various healthcare environments and surfaces [20,21], only recently has scientific literature started exploring the potential of UV-C devices in house and work environments [22]. The correct use of UV-C technology takes the following parameters into account: distance from the light source (m), spatial light distribution, radiant power (W), irradiance (W/m^2), inversely proportional to the square of the distance, and radiation times (min). This allows more accurate disinfection of objects that are exposed to an adequate dose of UV-C, where the dose (J/m^2) is the product of the irradiation time and irradiance [23]. Simulation models, that take into account the parameters described above make it possible to estimate the disinfection capacity of systems based on UV-C technology. In particular, once the dose corresponding to a specific reduction in microbial load has been established, they enable the relative UV-C irradiation times to be evaluated for each distance, and vice versa [24]. However literature about surface contamination and control in non-healthcare environment with this type of technology is scarce and every surface in every work environment can be a fomite.

For the purpose of this study the focus is shifted to cinema industry. It was forced to halt its production by the COVID-19 pandemic, especially in the first half of 2020: movie theaters and production studies had to close for months, heavily impacting the market [25]. As described by the 2020 THEME Report [26], redacted by the Motion Picture Association, the global box office market was $12 billion in 2020, 72% lower than 2019. From the same report, it is highlighted the fact that only 46% of the U.S./Canada population went to the cinema at least once in 2020, compared to 76% of population in 2019. Video cameras, in particular, are tools that are shared among the crew and have frequent contact with different parts of the body: these factors result in video cameras being a potential route of transmission via fomite colonization. And while a protocol for the protection of workers in this work sector was developed in 2020 [27], the experiments discussed in our study might be the first experiments involving the cinema industry and disinfection of commonly shared work tools, such as video cameras.

This study aims to evaluate the microbicidal efficacy of a new UV-C device for the disinfection of cameras and cinema equipment. Equipment like this are often contaminated by hand contact and proximity to the nose, mouth, ears and conjunctivae. The performance of the device will be analyzed by placing contaminated carriers with selected microbes at sensitive spots on the camera.

Materials and methods

The experiment was conducted between December 2020 and February 2021 at the Department of Molecular and Developmental Medicine, University of Siena, Italy. The UV-C device is a "Cartoni UV-C BOXER number BX0002", provided by Cartoni S.p.A. (Fig. 1). The UV-C boxer has a large sliding box-like container for safe loading and disinfection of multiple pieces of gear at the same time. There are 10 UV-C lamps, "OSRAM PURITEC HNS UV-C", at 255 nm (0.9 Watt/each) (OSRAM GmbH, Munich, Germany) equally distributed on the top of the internal chamber. All six internal walls are reflective, to allow the UV rays to reach every surface of the device to disinfect. If the box chamber door is not safely locked, a switch sensor placed directly on the device door does not allow the UV-C lamps to be turned ON. The UV-C lights are activated by closing the box and pressing the switch button. A timer control can be used to program switching ON and OFF the device to set disinfection cycles.

Three different types of experiments were conducted. The first is a test of inactivation of selected bacterial isolates at a fixed distance, with two exposure times and different carrier materials. The second experiment consisted of a disinfection test of a video camera with contaminated carriers attached in different spots of its surface. The third experiment involved an inactivation test for the SARS-CoV-2 virus placed in a plastic cap inside a polylactic acid support with two UV-C permeable quartz walls (on the upper and bottom part).

Fig. 1. The UV-C Boxer from Cartoni S.p.A.

First experiment

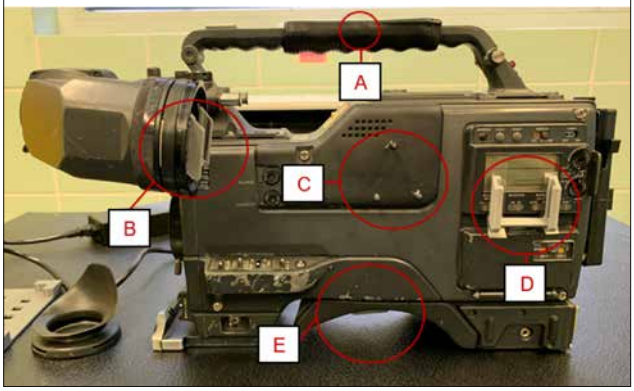
In this first experiment, two different bacteria were used: *S. aureus* ATCC 43300 and *E. coli* ATCC8739. A 0.5 McFarland inoculum for each bacteria strain was prepared, and from each inoculum, several scalar dilutions were performed. Then 100 µl of each dilution was spread on a 20 cm^2 carrier, with a sterile spatula, and let dry inside the laminar flow hood. Three different materials were selected: metal carriers, glass carriers and plastic carriers. Carriers were then positioned horizontally in the UV box, 50 cm from the upper light sources of the device. Carriers were exposed for 30 seconds and 60 seconds to UV-C rays. Additional carriers were placed out of reach of UV-C radiation, covered with an aluminium shell outside the device (positive controls). After the treatment, exposed and non-exposed carriers were transferred to 90 mm Petri dishes and 10 mL Dey and Engley (D/E) neutralizing broth medium was added (Liofilchem S.r.l., Teramo, Italy). Subsequently, the D/E medium was transferred to a 50mL Falcon centrifuge and spun for 40 minutes at 4500 rpm. Next, the supernatant was eliminated and the pellet re-suspended in 1mL D/E medium. Finally, 100 µl was transferred to Mannitol Salt Agar Petri dish (Oxoid Limited, Hampshire, United Kingdom), for *S. aureus*, Brilliance *E. coli*/Coliform Selective Agar Petri dish (Oxoid Limited, Hampshire, United Kingdom), for *E. coli*, and incubated at 36°C for 48 h. This experiment was conducted in triplicates.

Second experiment

The contaminated device used for this experiment is a Sonyh Ampex CVR (BVW) 400P video-camera (Sony, Tokyo, Japan) which was placed on the sliding container of the box. To conduct this study, it was necessary to locate selected spots on the video camera to place the test microbic sample following two criteria: 1) spots with a high frequency of contact with human skin and, thus, very likely to be contaminated in everyday use of the device; 2) spots where the UV-C light might not reach directly, to test the microbicide effectiveness of reflected light on the camera. Five spots were identified: Spot A, 23 cm from the light sources (handle position, direct to the light sources); Spot B: 30 cm from the light sources (ocular position, not direct to the light sources); Spot C: 33 cm from the light sources (lateral position, not direct to the light sources); Spot D: 34 cm from the light sources (keypad position, not direct to the light sources); Spot E: 50 cm from the light sources (shoulder pad position, opposite to the light source) (Fig. 2).

The test microorganism for this experiment was *S. aureus* ATCC 43300. On each spot, a 20 cm^2 plastic carrier was placed, and the *S. aureus* inoculum was spread on each carrier with a sterile spatula and left to dry inside a laminar flow hood. Positive control was also prepared with another 20 cm^2 plastic carrier which was left in the lab during the experiment, out of range of UV radiation. The concentration of the inoculum in the Treated Samples and Positive controls was $1.5x10^7$ CFU/mL for each spot. The video camera was exposed to the UV-C light inside the closed box for 3 minutes. After the treatment, the used protocol to prepare the samples was the same procedure used for the first experiment. This experiment was conducted in triplicates.

Fig. 2. The video camera and the position of the selected spots for experiment 2.



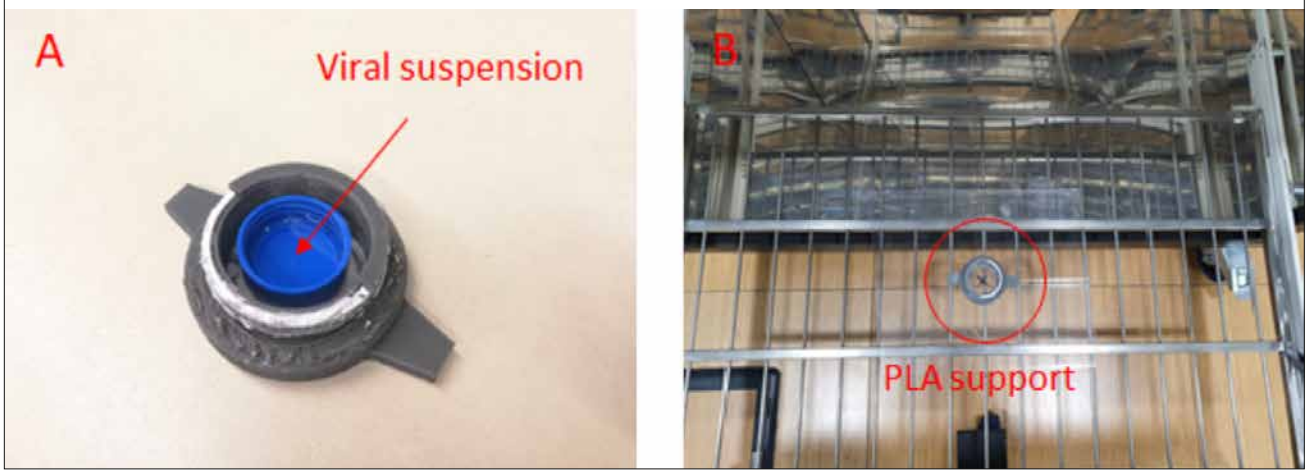
Third experiment

In the last experiment, SARS-CoV-2 was tested (Lot: SARS-CoV-2_COV2019 ITALY/INMI1) using the VERO E6 C1008 (ATCC CRL-1586) cell line as host cell. We have designed a support made of polylactic acid (PLA) then printed it with an FDM 3D-Printer Anycubic (Shenzhen Anycubic Technology Co., Hong Kong, China). At both ends of the PLA support, two quartz carriers (UV-C permeable) were placed and between them, a plastic cap with the inoculum drop placed inside of it. The PLA support was positioned at the centre of the sliding grid of the box (Fig. 3). The Inoculum consisted of with 100 µL of viral suspension. The suspension virus used was $10^{6.88}$ TCID50%/mL (6.88 expressed by Log_{10}). The device irradiated the surface for 3 minutes. Three samples inoculated with the virus were subjected to the action of the UV-C box as per protocol. In comparison, three samples were inoculated but not treated with UV to determine viral titer after recovery and examined immediately after inoculation. The collected suspensions were inoculated into a multi-plate into which the VERO E6 cell cultures were fixed. Plates were incubated for three days at 37°C ± 2°C at 5% CO_2 in a humidified atmosphere. After the exposure time, we tested the residual virus activity by evaluating the Tissue Culture Infective Dose of 50% (TCID50%).

Statistical analysis

In the database, the variables collected were the Petri dish ID, CFUs/mL, microorganism species and inoculum concentrations. Data analysis and statistical computations were performed using Microsoft Excel software (ver. 16) for preliminary statistical evaluations of empirical data and Stata software Ver 16 for the statistical analysis. The results of each experiment in triplicate were expressed as mean CFU/mL for each test for the experiments involving

Fig. 3. (a) the PLA support (grey part) used for the test. Inside the support, the viral inoculum has been placed in a plastic test tube cap (blue cap). (b) Placement of the PLA support on the metal grid of the device (view from above).



bacteria. The mean logarithmic reduction and its 95% confidence interval were calculated from the replicates data of the microorganisms and compared with positive controls.

Results

First Experiment

This experiment showed that the higher bacterial inactivation effect is reached for all two strains at 60 seconds, although at 30 seconds, there is a significant reduction in the bacterial load.

With a concentration of $1.5x10^7$ CFU/mL on a plastic carrier, the mean bacterial inactivation of *S. aureus* was 5.06 Log_{10} after 30 seconds of exposure to UV-C light and 5.96 Log_{10} after 60 seconds. *E. coli*, instead, on the same type of carrier and with the same concentration, was reduced to 4.56 Log_{10} after 30 seconds and 5.20 Log_{10} after 60 seconds. On a metal carrier, instead, the mean bacterial inactivation of *S. aureus* was 4.63 Log_{10} after 30 seconds and 6.72 Log_{10} after 60 seconds. *E. coli* on the same carrier was reduced to 5.14 Log_{10} after 30 seconds and complete inactivation of 7.48 Log_{10} after 60 seconds. Finally, considering glass carriers, the mean bacterial inactivation of *S. aureus* was 5.61 Log_{10} after 30 seconds and 6.96 Log_{10} after 60 seconds, while the reduction of *E. coli* was 6.13 Log_{10} after 30 seconds and complete inactivation of 7.48 Log_{10} after 60 seconds.

The lower concentration tested, $1.5x10^6$ CFU/mL, showed the following results: on plastic carriers, S. *aureus*' mean bacterial inactivation was 4.96 Log_{10} after 30 seconds and 5.68 Log_{10} after 60 seconds, while the mean reduction of *E. coli* concentration on the same carrier was 4.26 Log_{10} after 30 seconds and 5.90 Log_{10} after 60 seconds. *S. aureus* was reduced on metal carriers by 5.46 Log_{10} after 30 seconds and 6.48 Log_{10} after 60 seconds, while *E. coli* was reduced by 5.28 Log_{10} after 30 seconds and 6.04 Log_{10} after 60 seconds. Finally, on glass carriers, *S. aureus* was reduced by 6.22 Log_{10} after 30 seconds and 5,88 Log_{10} after 60 seconds, while *E. coli* was inactivated entirely after 30 seconds, same value consequentially after 60 seconds.

The highest reduction was seen in glass carriers, whereas the smallest reduction was seen in plastic carriers. The complete data can be seen in Table I.

Second Experiment

These experiments showed that after 3 minutes of UV-C exposure of the video camera inside the Cartoni UV-C BOXER, there is a significant reduction in the bacterial load. After a 3 minutes' exposure to the UV-C light inside the box, the mean bacterial inactivation in plastic carriers on Spot A was 6.33 Log_{10}; on Spot B was 4.74 Log_{10}; on Spot C was 4.83 Log_{10}; on Spot D was 4.89 Log_{10}; finally, on Spot E was 5.00 Log_{10} (Tab. II).

The results are similar with those obtained in the first experiment, despite different exposure times. The findings also highlight the direct and indirect (from reflection) effect of UV-C light on target objects.

Third Experiment

The tests showed that for the carriers located on the device grids, 5.37 Log_{10} reduction (>99,999%) was reached when tested against SARS-CoV-2, with an irradiation time of 3 minutes for all the three repetitions (Tab. III).

Discussion

Cinema studies work in different environments, from open spaces to little rooms, where maintaining a safe distance can be problematic, and equipment is shared. This pandemic represented a challenge to step up technologies and techniques to keep safety in every work environment.

We conducted this test to see if devices like the Cartoni UV-C box can be a practical solution to control fomites infection in a peculiar work environment like movie

Tab. I. CFU/mL logarithmic reduction of *S. aureus* and *E. coli* on plastic, metal and glass carriers after UV-C irradiation inside the box, experiment 1.

Bacteria	Carrier	30 seconds exposure			
		1.5 x 10^7 (CFU/mL)		1.5 x 10^6 (CFU/mL)	
		Mean	95% CI	Mean	95% CI
S. aureus	Plastic	5.06	4.73-5.40	4.96	4.74-5.17
	Metal	4.63	3.33-5.92	5.46	4.46-6.46
	Glass	5.61	5.51-5.70	6.22	5.71-6.73
E. coli	Plastic	4.56	3.95-5.16	4.26	3.43-5.09
	Metal	5.14	4.04-6.23	5.28	5.18-5.38
	Glass	6.13	5.87-6.39	6.48	6.48-6.48
Bacteria	Carrier	60 seconds exposure			
		1.5 x 10^7 (CFU/mL)		1.5 x 10^6 (CFU/mL)	
		Mean	95% CI	Mean	95% CI
S. aureus	Plastic	5.96	5.74-6.17	5.68	4.78-6.59
	Metal	6.72	5.25-8.20	6.48	6.48-6.48
	Glass	6.96	6.45-7.47	5.88	4.72-7.05
E. coli	Plastic	5.20	4.72-5.69	5.90	4.77-7.03
	Metal	7.48	7.48-7.48	6.04	5.19-6.89
	Glass	7.48	7.48-7.48	6.48	6.48-6.48

Tab. II. *S. aureus* ATCC 43300 CFU/mL logarithmic reduction on plastic carriers after UV-C irradiation inside the box, experiment 2.

Spot	Log_{10} reduction after 3 minutes exposure	
	Mean	95% CI
A	6.33	5.90-6.75
B	4.74	4.14-5.33
C	4.83	4.75-4.91
D	4,89	4.12-5.65
E	5.00	4.79-5.21

studios. We first wanted to test if there is any significant difference in the microbicide activity of the UV-C lamps between different types of surfaces. In the first experiment, the greatest reduction was observed on glass carriers, with the total abatement for *E. coli* and between 6 to 7 $\log_{10}$ (between 99.9998% and 99.99999% reduction) for *S. aureus* at one minute of exposure. In contrast, the smallest reduction was observed on plastic carriers. A possible explanation of the different abatements on the carriers may be attributable to a dissimilar hydrophobic condition of the materials that do not allow the same dispersion of the drop on the carrier. The latter may cause a superposition of microbes exposed to UV-C rays. Coughenor et al. showed how MRSA survives more on plastic and vinyl, posing as a hypothesis that they have a microscopically coarse structure, which provides more protection from dehydration, comparing this to glass, instead, being a smooth surface and having the shortest survival time [28].

The next step was to see how the UV-C box performed on actual equipment from the carrier. As previously stated in the experiment setup, while selecting the spots, we considered not only the direct or reflected exposure to the UV light but mainly areas of high contact with different body parts. While utilizing a video camera, the operator makes direct contact or close contact with several body districts such as the eyes, hands, mouth and ears.

The microbiological results showed a significant reduction in all five spots after 3-minute irradiation inside the UV-C box. This experiment showed how the logarithmic reduction also depends on the carriers' position. Direct or reflected on the walls, the light irradiates the selected spots differently. The highest decrease was observed in spot A (handle position), with a 99.99995% reduction of bacterial load after 3 minutes of exposure, while the worst logarithmic reduction was observed in spot B (ocular position), with an abatement of 99.998%. Spot B was selected because it is in close contact with the human eye, possible contamination with tears, and proximity with the conjunctival mucosae. As previously stated, MRSA can be pathogenic when transmitted via unanimated surfaces. While MRSA

Tab. III. SARS-CoV-2 logarithmic reduction on the carrier after UV-C irradiation, experiment 3.

Repetition	Time of exposition	TCID50% untreated control (Log_{10})	TCID50% of virus after treatment (Log_{10})	TCID50% reduction (Log_{10})
1	3 min	6.86	1.5*	5.36
2	3 min	6.87	1.5*	5.37
3	3 min	6.87	1.5*	5.37

* The value of Log TCID50 = 1.5 means total viral inactivation

keratitis and post-operative endophthalmitis have been reported leading to poor visual outcomes, these kinds of infections are still very uncommon, and not only the percentage of MRSA eye diseases are quite low, but also they generally present with a mild clinical history and a good response to first-line therapy [29]. Spot C, where the box reached a 99,998% reduction, was identified as a surface in contact with the ear, while Spot D is crucial because the presence of buttons and a display there make it a high contact zone. Considering how bacteria can widely contaminate computer keyboards [34] and mobile phone surfaces [35] due to their frequent utilization. The results obtained here of abatement of 99,998% are in line with other studies performed on different settings [30, 31]. To be noticed was the interesting result obtained in spot E (shoulder pad position), with a microbe reduction of 99.999%, where the light could only irradiate the plastic carrier due to the reflective wall under the positioning grid.

We lastly tested the virucide activity on SARS-CoV-2. A mean reduction of 5.37 Log_{10} across all three repetitions of the same test was reached in a 3-minute exposure.

Regarding SARS-CoV-2, a significant number of studies showed the persistence of the virus in different types of surfaces and materials. Gonçalves et al. in 2021 showed that, while COVID-19 can be found in a wide range of surfaces with different materials and environments, the availability of pathogenic viruses on them is yet to be demonstrated, so it is not yet clear if a COVID-19 infection from fomites is possible or not [32]. Considering the obtained results, the same considerations discussed in the previous paragraphs about the different camera spots can also be done for SARS-CoV-2: the virus presence in the conjunctival sac can be a source of spread, and ocular manifestations may be part of the early symptoms of the disease, as stated in the meta analysis by Zhong et al. [33]. The same study highlighted how conjunctival swab tests for viral RNA resulted in positive in 3.9% of all patients. The study could not confirm nor exclude the possibility of a SARS-CoV-2 infection due to the eye as a potential source of disease, also considering how the percentage of positivity of swabs does widely vary in literature [34-36].

In all three experiments, the UV-C box managed to reduce the contamination in different samples in a short span. These results confirmed the efficacy of UV-C disinfection against microbes such as MRSA and SARS-CoV-2, aligning with other studies. The interest in UV-C disinfection comes from the ability to design easy-to-use devices in everyday routine and the reported resistance of some bacterial strands to common chemical disinfectant agents [37, 38].

In the film industry segment, where expensive devices are used and shared every working day, it is crucial to preserve the integrity of the materials the devices are made of. UV-C after long and repeated exposures can irreversibly damage irradiated surfaces [23]. From the tests performed, we believe that the duration of the disinfection cycle is not sufficient to alter the physical properties of the camera and the film recorded inside, even with consecutive cycles of irradiation. Also, it must be considered how chemical disinfectants may stiffen plastic if not used appropriately and with the appropriate chemical for every machine.

Also, UV-C disinfection can represent a more environmentally friendly alternative to chemical disinfection. Although the lamps used in the Cartoni UV-C box do have mercury among their components, which represents a costly waste to dispose of, there is an increasing focus on LED UV-C lamps, which may become a solution to avoid toxic wastes and to lower the energy demands of the disinfection devices.

One of the possible limitations of this study is that there are no data regarding the energy doses on every spot on the camera, not allowing this study to make a thorough consideration on the possible values of dose/microbe abatement on every step area. While we can expect a lower value on sites where only reflected light could reach the surfaces, possibly related to the higher microbial reduction on Spot A (directly facing the UV-C lamps), identifying a technical dose/reduction value can be a point of interest for future studies. Another limitation of this study is that it does not report any information about the potential transmission of the microbes from the treated surfaces to the camera operators and vice versa, like in hand to surface contamination. Although there's plenty of evidence of persistence of the microbes in different surfaces and environments [39, 40] the evidence of transmission of SARS-CoV-2 via fomites is low [41] and needs further research. In addition, the opportunity to expand current knowledge in the field of UV disinfection, even at frequencies other than UV-C [42], could add information on the resistance mechanisms of microbes that persist for long periods on treated surfaces.

Conclusions

The microbiocidal activity of the UV-C boxer was effective on three different types of materials in a short time of exposure to UV light. Effective disinfection can be obtained with UV-C regardless of the position of the surface with direct or reflected rays. Further engineering and research applications on this technology could encourage companies and workers outside the healthcare context to use this type of device to maintain a safe working environment. In combination with complementary disinfection techniques (*e.g.* chemical disinfectants) and adherence to established best practices, the use of this innovative tool has the potential to improve the overall safety standards of working environments, in particular by effectively reducing the risk of microbial contamination of various cinema equipment and surfaces.

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Data availability statement

The data presented in this study are available on request from the corresponding author.

Institutional review board statement

Not applicable.

Informed consent statement

Not applicable.

Conflict of interest statement

Cartoni S.p.A. financed the University of Siena, with G.M. as the principal investigator. G.M. did not receive any personal funds for the research. G.M. and G.C. are the co-founders of the company egoHEALTH which received Cartoni S.p.A. funds to cover part of the investigation. The company Cartoni S.p.A had no role in the test design, data collection or analysis, decision to publish, or preparation and discussion of the test results in the manuscript.

Authors' contributions

GM, GC: conceptualization; GM: methodology; GC, SL: software; NN, IDP: validation; GC: formal analysis; DA, IDP: investigation; GM: resources; SL, DA: writing-original draft preparation; SL, DA: writing-review and editing; NN: visualization; GM: supervision, GM, GC: project administration; GM, GC: funding acquisition. All authors have read and agreed to the published version of the manuscript.

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