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Object: Bibliographic review report: Use of Puricraft UV-C system to inactivate SARS-CoV-2

UV-C based systems have important roles to play in battling bacteria, molds, yeasts, and viruses in air, on surfaces, and in water. Based on review literature, recent publications report that SARS-CoV-2 is sensitive to oxygen, and UV light could alter spike (S) protein and genomic profile of the virus (Shirbandi et al. 2020; Darnell et al., 2004; Darnell et al., 2006).

Non-contact disinfection technologies are highly desirable, and UV radiation, in particular UV-C (200–280 nm) has been suggested to be able to inactivate different viruses, including SARS-*Coronavirus*. The interaction of UV-C radiations with viruses has been extensively studied, and direct absorption of the UV-C photon by the nucleic acid basis and/or capsid proteins leading to the generation of photoproducts that inactivate the virus was suggested to be one of the main UV-C-associated virucidal mechanisms (Biasin et al., 2021).

Even before the experimental researches conducted on SARS-CoV-2 during last year, several articles reported that UV-C is able to reach a high level of inactivation of a near-relative of SARS-CoV-2 virus (i.e., SARS-CoV-1, tested with UV_{254}) (Kariwa et al., 2006; Centers for Disease Control and Prevention, 2008). In 2020, International Ultraviolet Association (IUVA) declared that similar results would have been expected with SARS-CoV-2, by applying UV-C aiming to adequately reach any remaining viruses on surfaces. UV light, in UV-C range, is capable of inactivating at least two other species of *Coronavirus*, closely related to COVID-19's virus: SARS-CoV-1 (Tsunetsugu-Yokota et al., 2008) and MERS-CoV (Bedell et al., 2016; Rutala et al., 2020). Three studies published in 2020 reported UV dose-response behavior of SARS-CoV-2 or surrogate viruses: Bianco et al., 2020 reported that a UV_{254} dose of 3.7 mJ/cm^2 reduced the 3 log_{10} units of SARS-CoV-2 load in water. Inagaki et al., 2020 indicated that a UV_{280} dose of roughly 38 mJ/cm^2 reduced SARS-CoV-2 load of 3 log_{10} units. Buonanno et al., 2020 reported that far-UV-C, at 1.2 to 1.7 mJ/cm^2 doses, reduced at least 3 log_{10} units of Coronaviruses alpha HCoV-229E and beta HCoV-OC43 (using UV_{222} doses of 1.7 mJ/cm^2 and 1.2 mJ/cm^2, respectively).

As of some of the microorganisms tested during Check Up's Puricraft experiments, studies conducted on *Escherichia coli* and *Salmonella* spp. inactivation capability, using UV-C light, reported the 1 to 3 log_{10} reduction of the bacterial loads, employing UV-C light at fluences from 5 to 3 mJ/cm^2 (Holck et al., 2018), up to 18 mJ/cm^2 to obtain the 99.9% die-off of *Salmonella* Typhymurium (Gayán et al., 2012): such doses are higher than those needed to inactivate SARS-CoV-2 virus and its surrogates.

Since the beginning of COVID-19 pandemic in March 2020, several studies reported UV dose-response behavior of SARS-CoV-2:

- Gidari A. et al., 2020 tested a monochromatic UV-C (254 nm) lamp on three different surfaces (plastic, glass and stainless steel). On plastic surface, an UV-C dose of **10.25 mJ/cm^2** caused a titer reduction of about 2 logs. On stainless steel, the UV-C doses of 10.25 mJ/cm^2 (21 s) and **16.59 mJ/cm^2** (31 s) reduced viral titer of 3 logs. On glass, 10.25 mJ/cm^2 (21 s) was sufficient to eradicate SARS-CoV-2.
- Ruetalo,et al., 2020 evaluated the efficiency of UV-C irradiation to inactivate surface dried SARS-CoV-2, demonstrating that short exposure of high titer surface dried virus (3*10^6 IU/mL) with UV-C light at 254 nm at two second irradiation time, and a dose of **80 mJ/cm^2** at 5 cm distance. From the speed of the "slow" and "fast" moving regimens we calculate a UV-C dose of **2.13 mJ/cm^2 (slow) and 0.66 mJ/cm^2 (fast)**. The tests resulted in a total reduction of SARS CoV-2.
- Biasin et al., 2021 reported that at a virus density comparable to that observed in SARS-CoV-2 infection, an UV-C dose of just **3.7 mJ/cm^2** is sufficient to achieve a more than 3-log inactivation without any sign of viral replication. Moreover, a complete inactivation at all viral concentrations is observed with **16.9 mJ/cm^2**. The results could explain the epidemiological trends of COVID-19 and are important for the development of novel sterilizing methods to contain SARS-CoV-2.
- Mariita M. et al, 2021 showed that variations in UV-C wavelengths have an impact on the dose required for SARS-CoV-2 disinfection and alter the rapidity and efficacy of virus chain disruption. In fact, they have proven in their work that to achieve a 3-log abatement with a time of 5 seconds, the doses required increase as the wavelength of the UV-C rays increases. More precisely a 254 nm lamp requires **4.3 mJ/cm^2**, a 265 nm lamp requires **5.1 mJ/cm^2** and for a 268 nm lamp is necessary a dose of **6.25 mJ/cm^2**.
- Retablo et al., 2022 reported that a relatively low average UV-C dose of **0.42–0.51 mJ/cm^2** at 254 nm allows for more than two-log reduction in aerosolized SARS-CoV-2 infectivity.

It is important to premise that available data are not comparable in absolute, taking into account that the majority of matrices examined in the bibliography (surfaces), apart from the research performed by Retablo et al., 2022, are different from the one (air) considered in the present study.

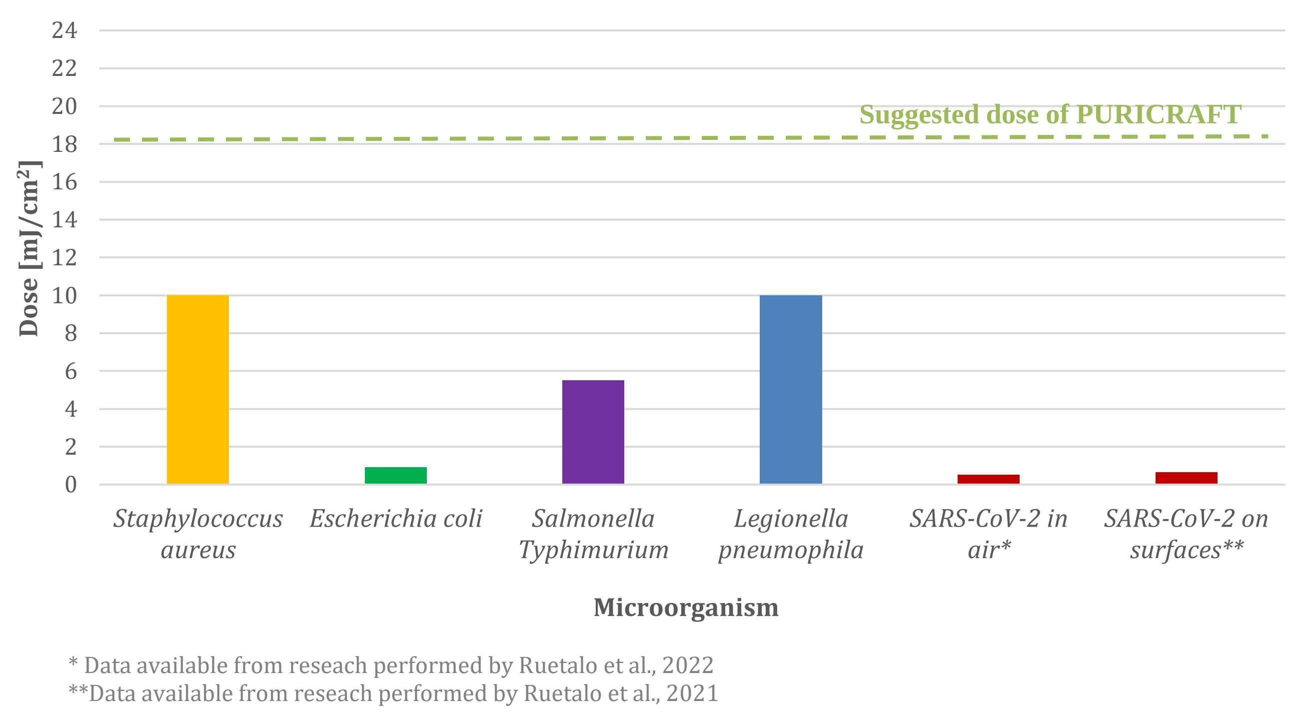
Hence, considering the 100% inactivation doses for *Escherichia coli* (i.e., setting C, 6 mJ/cm^2) and *Salmonella* Typhimurium (i.e., setting F, 15 mJ/cm^2), applied using Puricraft UV-C system in the previously described tests, and based on the available bibliography, stating a range between **0.41 and 0.66 mJ/cm²** dose to inactivate SARS-CoV-2, **it can be hypothesized that the Puricraft system may be able, at the highest doses tested** (setting C, 6 mJ/cm², and F, 15 mJ/cm²), **to reduce the viral load of SARS-CoV-2**.

According to the results of the experiments, and the outcomes collected from the peer-reviewed articles' review process, the obtained results for marketing aims, summarized in **Table 1**, may be graphically expressed into a figure reporting the dose comparison between the UV-C die-off doses for tested microorganisms, compared to SARS-CoV-2 doses (Figure 1).

Figure 1. Absolute and standardized microorganisms die-off doses according to the results of the experiments employing Puricraft's UV-C system, and the outcomes collected from the peer-reviewed articles' review process (Standardized contact time: 5 min).

Source	Microorganism	Dose [mJ/cm²]	Contact time [s]	Standardized dose [mJ/cm²]
Experiments conducted using Puricraft system	***Staphylococcus aureus***	10	300	10
	Escherichia coli	6	45	0,9
	***Salmonella* Typhimurium**	15	110	5,5
	Legionella pneumophila	10	300	10
Data collected from peer-reviewed articles available online	**SARS-CoV-2 in air***	0,51	300	0,51
	SARS-CoV-2 on surfaces**	0,66	300	0,66

Figure 2. Standardized microorganisms die-off dose employing Puricraft's UV-C system produced by Check Up srl (Contact time: 5 min).



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