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On the Disinfection Chain as a New Technique for Economic and Chemical Free Disinfection of Public Places from Viruses

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Abstract

For killing viruses such as coronaviruses (CoVs), researchers suggested disinfection chains of ultraviolet (UV)-C lamps supported by holding stands. Such chains can be folded easily for carrying purpose, and the length of the system could be changed following the need. Such uncomplicated device could be utilized for cheap, reusable and chemical free disinfection of public places; such setup is as well appropriate to neutralize the airborne viruses, even if the application of disinfection should be realized in absence of humans to avert the hazardous influence of UV rays on skin. On the other hand, chemical disinfectants are largely utilized on common touch surfaces in public settings, as a means of controlling the Cov propagation. Nonetheless, the continuous introduction of such dangerous chemicals can exacerbate the growth of biocide-tolerant and antibiotic-resistant bacteria on those surfaces and allow their direct transfers to humans. For these reasons, UV disinfection technology may be promising for dealing with such CoVs.

Keywords: Coronaviruses (CoVs); Ultraviolet (UV) ray; Disinfection chain; *Severe acute respiratory syndrome coronavirus-2* (SARS-CoV-2); SARS-CoV-2 stability; Microorganisms (MOs); Wastewater treatment plants (WWTPs).

1. INTRODUCTION

During the last twenty years, many harmful viruses have contaminated humans [1-3]. As an example of these manifestations of viral contaminations, the Influenza type A virus, Middle East Respiratory Syndrome (MERS), Severe Acute Respiratory Syndrome (SARS) are well-known [4-6]. During the second half of 2019, COVID-19 pandemic emerged [7-9]. Thus, it remains so demanding to dominate the diffusion of SARS-CoV-2 [10-12]. Investigations are dedicated to search a solution to decrease the propagation rate of contagion in such dangerous condition [13-15].

The most frequent method to sanitize the public places is by employing the disinfection spray over the surfaces [16-18]. Nevertheless, several unwanted results of immoderate usage of disinfectants such as formation of chemical residue [19-21] which are poisonous to humans and nature have been noticed [22-24]. Moreover, utmost cares require to be followed during preparations of the disinfectant spray [1, 17]. Consequently, suggesting inexpensive and chemical free disinfection of public places against SARS-CoV-2 virus is so vital to diminish the diffusion of contamination [25-27]. Ultraviolet (UV) light [1, 28, 29] has been employed to disinfect the clinical equipment because it does not form chemical residue. For such justification, the UV irradiation founded technique can be used to sterilize the clinical rooms as well as different public places [30]. Debnath and Islam [1] suggested a UV-C light founded portable disinfection chain system to kill viruses existing in the different public places comprising clinical rooms. Following the demand of public places, the number of portable disinfection chain can be regulated or modified. Further, UV-C light is observed to be efficient in neutralizing the airborne viruses during passing through the air [1, 17].

This work focuses on the promising research axis proposed by Debnath and Islam [1]. Section 2 defines the associated researches concerning the fresh advances registered to deal with COVID-19 dispersal. Section 3 describes the procedure proposed to promote the chemical free disinfection system. In Section 4, the efficiency of the suggested model is analyzed.

2. ASSOCIATED RESEARCHES

Throughout the epidemic of fresh CoV, numerous scientists suggested various techniques with a view to deal with the propagation of SARS-CoV-2 virus [31-33]. The progress in dominating the COVID-19 diffusion has been performed both in social aspects [34-36] and via technical forms [37, 38]. To fight the COVID-19 sudden appearance, it is so crucial to utilize face masks and keep social distancing in public places [1, 17]. Nonetheless, for efficient dominance, it remains obligatory to disinfect the public places regularly besides continuing the social distancing and employment of face shields or face masks. Cobb and Seale [39] evaluated the influence of social distancing on the extension of COVID-19 cases in the USA. They found that the shelter-in-place order is able to diminish the diffusion of COVID-19 even if such stay-at-home policy could not be practical to execute for longer time since it has rival impact on both economy and society. All such actions to block the propagation of the pandemic cannot be useful if public places are not purified duly and frequently [1, 17].

As seen above, the most remarkable procedures to be followed remains dominating the contagion [17]. To reach that, continual disinfection of public places stays needed in the present situation [1]. Besides the public places, it is as well indispensable to purify all the personal protective kits. In such consideration, scientists [40] suggested a set-up to sterilize N95 respirators and face mask rapidly employing steam treatment. Nevertheless, it remains fundamental to grasp the filtration performance of such device in situation of short cycles of stream treatment. Presently, sterilizing air and surfaces could be performed utilizing chemical founded disinfection spray or via employing chemical free disinfection system [41-43].

Lately, researches tend to depict several chemical free disinfection techniques utilizing ultraviolet (UV-C) irradiation that have been suggested for different aims [28, 29, 38]. Debnath [37] presented a UV-C beam founded wooden box that is able to purify any food items kept inside it. Moreover, any small size commodity (such as hand watch, wallet, etc.) could as well be treated employing such technique [1, 17].

Ren et al. [38] examined the constraint of medical air disinfection utilizing UV-C light to minimize the spread of air borne SARS-CoV-2 virus. They noted that people living inside UV radiation circulated air area were free from the influence of such pathogen [1, 17]. Beside food items, chemical founded disinfection stays inappropriate in clinical utilizations [44-46]. Armellino et al. [47] noticed the functionality of UV beam founded disinfection technology to sterilize clinical tools.

3. METHODOLOGY

This part explains suggested strategy and the applied background of the technology in specifics.

3.1. Conceptualization

It is established that UV irradiation is efficient in decontaminating the surfaces, objects and food items versus different types of viruses and additional pathogens [1, 47, 48]. UV beam is able to decontaminate the clinical equipment [47] without forming any chemical residue [30]. This is why the UV light founded disinfection technology could be used to purify the clinical rooms or any other public places [1, 17]. There are three classes of UV radiations: UV-A (315-400 nm), UV-B (280-315 nm), and UV-C (100-280 nm) [28, 29]. Fig. 1 depicts the place of UV rays in the electromagnetic spectrum [1, 17].

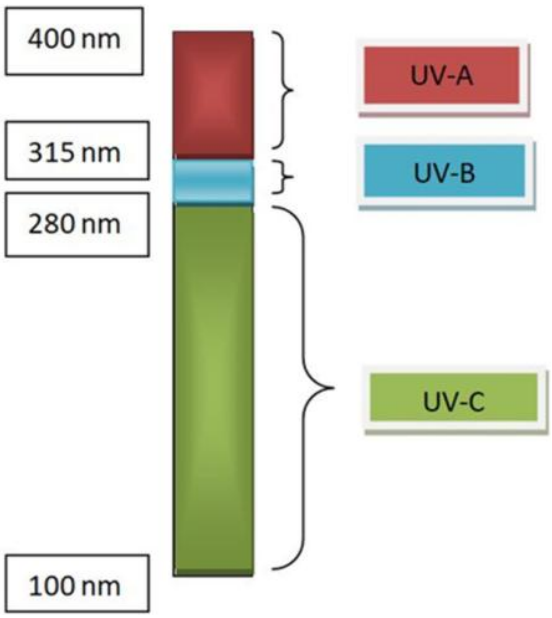

Fig-1: Place of UV radiations in electromagnetic spectrum [1]

Practically, it has been prove that the presence of active microbes is decreased under the subjection of UV-C radiations in the surfaces. The level of survival of virus on any surface is a function of the intensity of UV light as well as the subjection period. Such connection could be put together in Eq. (1) [48]:

$$N_{uv} = N_0 e^{-kIt} \quad (1)$$

where N_{uv} is the concentration of virus (in plaque forming unit, PFU/mL) survived on an surface after exposure to UV light for a time t (s); N_0 is the virus concentration (PFU/mL) on an surface which is not exposed to UV light; I is the intensity of UV light ($\mu W/cm^2$); and k is a constant related to microorganism susceptibility (cm^2/mJ) [1].

Ratio between concentration of virus after exposure to the concentration of virus before exposure, known as Survival Fraction (SF), may be formulated by Eq. (2) [1]:

$$SF = \frac{N_{uv}}{N_0} \quad (2)$$

Disinfection depends on the degree of microorganism susceptibility (cm^2/mJ) [1]. For a microorganism with less susceptibility level, more time and higher intensity rays are needed for disinfecting [49-51]. Killing microorganisms [52] could be performed with a low intensity UV-C light by exposing it for a longer time. Besides that, the identical performance may be realized in lesser period via applying higher intensity UV-C rays in process. Furthermore, UV-C radiation could neutralize the airborne viruses throughout passing across the air [53].

3.2. Suggested methodology

With a view to purify surfaces from viruses, Debnath and Islam [1] fabricated chains of UV-C lamp. They prepared such disinfection chains in such a fashion that they could be folded easily for carrying purpose [1]. Three disinfection chains fabricated with UV-C lamps are put in the upper, middle and lower portions through the holding stands as illustrated in Fig. 2. Series of such setup are put in the space existing between the columns of objects. As an illustration, while sterilizing a class room, the developed setup may be kept in between the benches. While in case of shopping malls, it can be put in between the object racks. Following upon the demand of public places, the number of portable disinfection chains can be modified or set. In such prototype setup, there are a total of nine chains. Each chain possessing a length of 90 cm consists of three UV-C lamps. The length of each UV-C lamp is 30 cm. The gap between two holding stands is 100 cm after taking into account the length of lamp holders. The structure has a height of 180 cm while the gap between the each row of chains is maintained 80 cm. The structure is conceived to guarantee the occurrence of UV-C light in all surfaces where the virus could exist. Such dimensions could be modified following the necessity and size of the disinfection room or chamber [1].

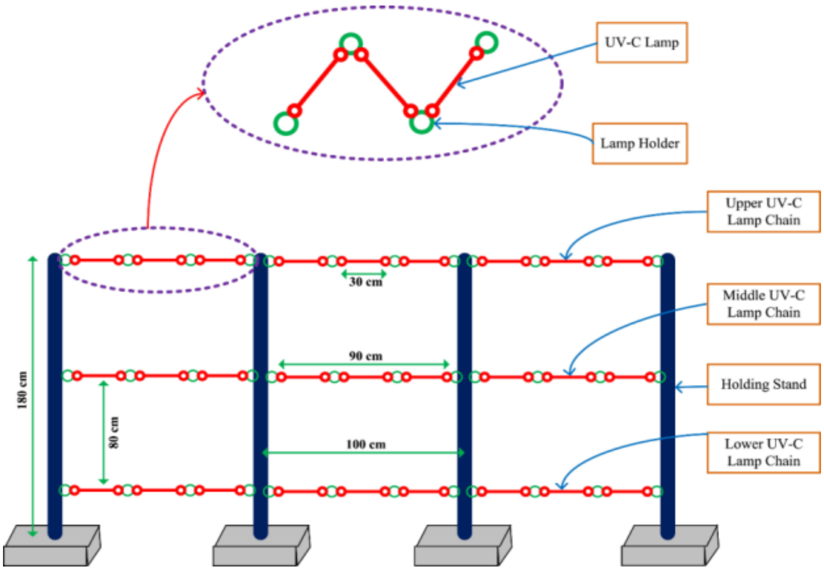

Fig-2: Disposition of disinfection chains with UV-C lamps [1]

To position the setup, it is crucial to supply the power in absence of humans for keeping the safety criteria [54]. Following connecting such network of systems with the power supply, all the entry doors must be closed. Such system can be extended with the holding stands following the dimension and demand of the public place. Further, a small setup could be utilized frequently with spatial variation to decontaminate a large place; however, it needs more time juxtaposed to the former case [1].

4. PERFORMANCES AND DEBATES

This part describes the efficiency of the device that is developed by Debnath and Islam [1]. It contrasts the efficiency of such process with the traditional disinfection technique. It also examines the requested preventive procedure to be followed during using the disinfection apparatus. Further, this part defines utilizations of the suggested device.

4.1. Efficiency discussion

The setup efficacy has been evaluated for different light intensity values at several periods of application. Table 1 presents the relationship between Survival Fraction (SF) and time (t) and Table 2 lists the features between SF and light intensity (I). Such relations are as well shown in Figs. 3 and 4, respectively. Table 3 defines the procedure for decontamination of such public places [1].

Table-1: Relationship between Survival Fraction (SF) and time t (s) [1].

Serial No.	Period t (s)	Survival Fraction (SF)		
		Intensity I (mW/cm^2) = 1	Intensity I (mW/cm^2) = 3	Intensity I (mW/cm^2) = 5
1	0	1	1	1
2	1	0.686	0.323	0.152
3	2	0.470	0.104	0.023
4	3	0.322	0.034	0.003
5	4	0.221	0.011	5×10^{-4}
6	5	0.152	0.003	8×10^{-5}
7	6	0.104	0.001	1×10^{-5}
8	7	0.071	3×10^{-4}	2×10^{-6}
9	8	0.049	1×10^{-4}	3×10^{-7}
10	9	0.034	4×10^{-5}	4×10^{-8}

Table-2: Relationship between Survival Fraction (SF) and intensity (I).

Serial No.	Survival Fraction (SF)	Intensity I (mW/cm^2)		
		Time t (s) = 1	Time t (s) = 5	Time t (s) = 10
1	0.01	12.2	2.4	1.2
2	0.02	10.4	2.1	1.0
3	0.03	9.9	2.0	0.9
4	0.04	8.5	1.7	0.8
5	0.05	7.9	1.6	0.7

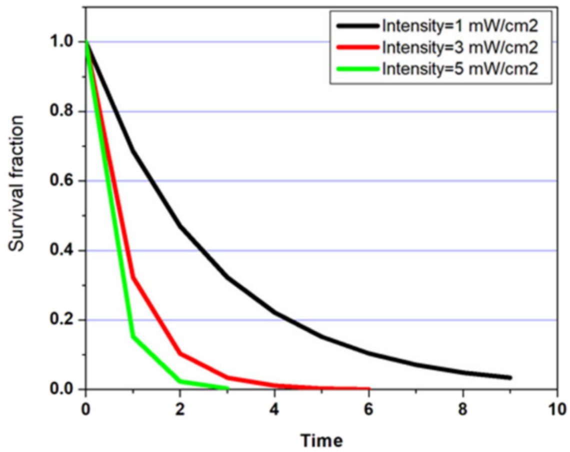

Fig-3: Relation between Survival Fraction (SF) and time t (s) when intensity I (mW/cm^2) is constant [1].

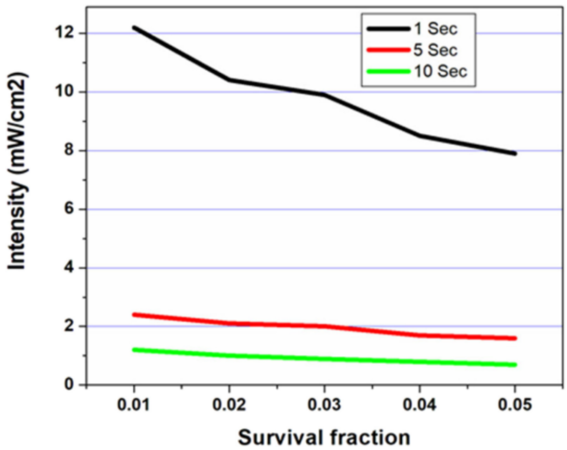

Fig-4: Relation between Survival Fraction (SF) and intensity I (mW/cm^2) when time t (s) is constant [1].

Table-3: Strategy for disinfection of various public places from SARS-CoV-2 [1].

Serial No.	Domain of disinfection	Strategy	Is absence of humans ensured?
1	Shopping mall	Disinfection using disinfection chains during lunch period and after closing	Yes
2	Classrooms or office rooms	Disinfection using disinfection chains during lunch period and after closing	Yes
3	Public transport systems (Aeroplane, train, bus)	Disinfection using disinfection chains after reaching to the destination and before starting a new journey	Yes

Similarly, Kitagawa et al. [55] established the performance of 222-nm UVC irradiation on viable SARS-CoV-2. They proposed that such technique could be utilized for infection prevention and control against COVID-19, not only in unoccupied spaces but also occupied spaces. More estimation of the safety and performance of 222-nm UVC irradiation in decreasing the infection of real-world surfaces and the transmission of SARS-CoV-2 is requested.

n the same context, the disinfecting features of sun (heat [56] and UV radiation) [57-59] are convenient in warm sunny regions to rid beach sand of coronavirus particles, if existing. Efstratiou and Tzoraki [60] focused on the pathway of natural decontamination given by the sun on coronaviral particles that may find their way onto beach sand. They affirmed that heat and UV radiation [61] produced by the sun eliminate the virus infection potential [60].

Analyzing data depicts that the disinfection level could be enhanced in two manners: (1) For a specific intensity of radiation, degree of disinfection can be elevated via augmenting the time of purification; (2) also for a defined period of application, killing level could be enhanced through elevating the intensity of beam (Fig. 5).

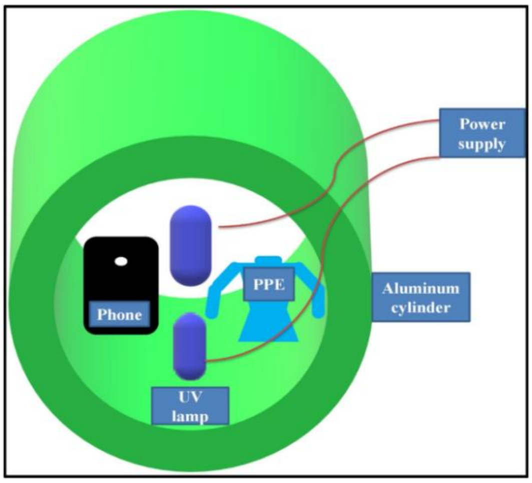

Fig-5: Suggested design for UV exposure cavity to demobilize the new COVID-19 that could be existing on the surfaces of various objects (e.g., phone, key, cloths, etc.) [17].

4.2. Safety measures and usages

As UV-C radiation is very dangerous to human skin, it is vital to perform the decontamination method in a closed domain so that the UV radiation could not fall directly on the body of any human being [1,54]. To satisfy such fundamental safety measure, users are alerted to supply power to the network externally by putting the electrical power switch ON from outside the disinfection place. Such exigency could be meet via running the electric switches from a place where the UV-C light cannot reach [1].

Such developed process stays convenient to sterilize the public places of different size such as shopping mall, classrooms, comprising the public transport systems such as aeroplane, train, bus after each operational phase due to its flexible structure [1].

4.3. Comparative analysis

Such decontamination technique possesses numerous characteristics: (1) it is an uncomplicated apparatus that could be conceived with little practical knowing; (2) such setup remains reusable, so the cost of decontamination is decreased greatly; (3) such sterilization device is a chemical free disinfection process and it does not form any chemical waste; (4) this is a flexible and portable apparatus since the UV lamps chain could be folded readily for carrying intent; (5) such technology kills airborne virus when it passes through the air [1].

Table 4 presents the juxtaposition of the efficacy of the developed method with the classical disinfection method [1].

Table-4: Juxtaposition of the suggested technology with classical decontamination procedure.

Serial No.	Parameter	Suggested technology	Conventional process
1	Reusability	Present	Absent
2	Chemical free disinfection	Yes	No
3	Deactivation of airborne virus	Present	Absent
4	Time requirement	Less	More
5	Human effort	Required in less amount	Required in more amount

The medical device industry replies upon significant lethality of predetermined populations of a biological indicator (BI) that is typically a recalcitrant bacterial endospore (e.g., Geobacillus stearothermophilus or Bacillus atrophaeus) (Fig. 6) [62]. For such aim, such BIs are accurately chosen since they are more resistant to that of pathogens comprising COVID19 [63-65] that are usually orders of magnitude more sensible to identical applied lethal stress [62, 66, 67] (Fig. 7).

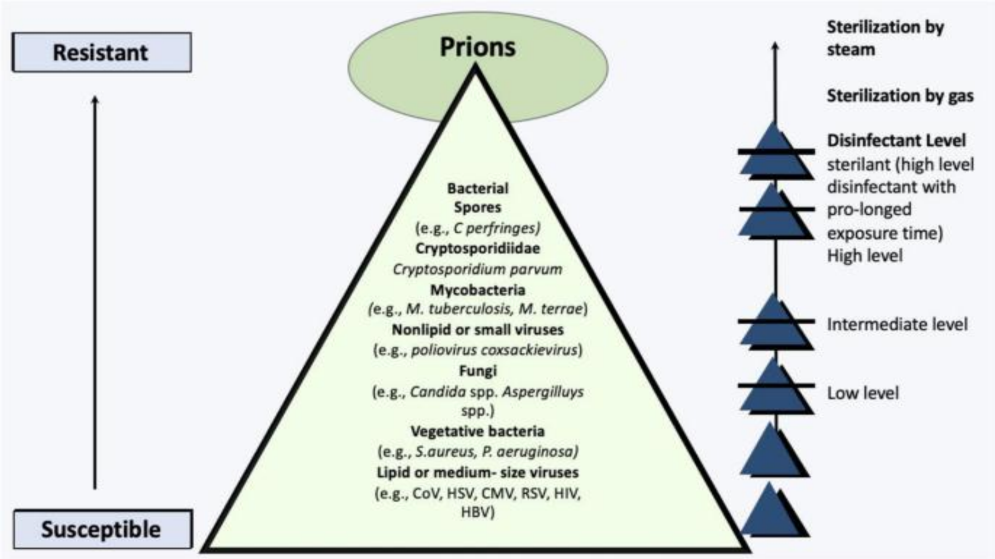

Fig-6: Pyramid of resistance of increasing resistance to disinfection and sterilization [62].

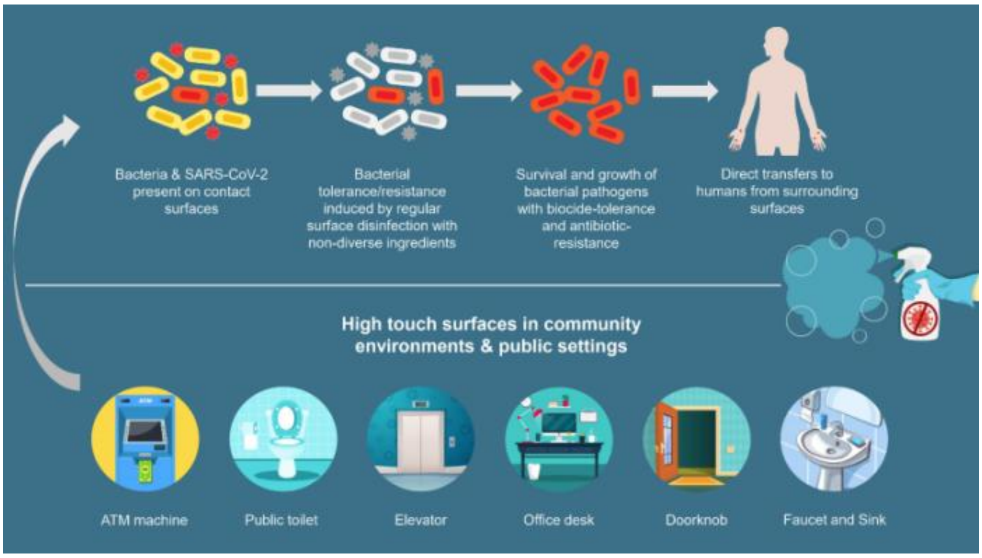

Fig-7: A schematic illustration on the probable growth of disinfectant-tolerant and antibiotic-resistant bacteria on contact surfaces in community and public settings, forming dangers of direct transfers to humans. With a highly non-diverse spectrum of biocidal agents in disinfectant products approved for COVID-19, these unintended consequences may arise from the regular and intensive surface disinfecting during COVID-19 and perhaps extended to the post-pandemic area [67].

5. CONCLUSION

1. During the actual COVID-19 pandemic case, a cheap and flexible decontamination device is able to contribute considerable to dominate the contagion of SARS-Cov-2 virus [1]. Taking into account the demand of persistent sterilization of various public places and the hurdle of economic restrictions, reusability is a significant factor of disinfection. An additional feature remains that chemical decontamination stays inconvenient to employ in several implementations like sterilization of clinical room, food shop, etc. In order to address such difficulties, a low cost and easy decontamination chain founded system has been proposed for chemical free disinfection of public places comprising the public transport system from SARS-CoV-2 throughout such pandemic era. The UV-C ray exposure founded sterilization chain remains reusable and flexible to perform thanks to its foldable structure. Such technology is as well appropriate to neutralize the airborne virus [68]. Suggested device needs lower human effort and less time (3 min) juxtaposed to the classical disinfection method. Nonetheless, protective means have to be followed to avert the toxic influence of UV-C light on human skin [1].
2. COVID-19 airborne diffusion has not been until now proved; fecal shedding has been noted from some patients, even if the viability of the virus has been evidenced at low levels [18]. Moreover, founded on the investigations on surface water, wastewater [21,69,70], sludge and bio-solid waste, the subsistence of SARS-CoV-2 would result very

low with temperatures higher than 20°C, and the demobilization rate of CoV is mostly higher than other examined viruses. The identical consideration can be adopted for hazard risk coming from potentially contaminated food, for which CoV persistence was reported for not more than 72 h of storage at 4°C. On inanimate surfaces, strains of CoV genus are capable to surviving up to nine days, but result extremely labile, being inactivated with really low concentrations of disinfectants [18].

3. While the existence of SARS-CoV-2 on inanimate surfaces stays likely, washing hands and methodical disinfection practices have to diminish the probabilities of diffusion of the CoV by such possible way of contamination [41].

6. ACKNOWLEDGMENTS

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