Surface Disinfection to Protect against Microorganisms: Overview of Traditional Methods and Issues of Emergent Nanotechnologies

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Abstract: Sterilization methods for individuals and facilities are extremely important to enable human beings to continue the basic tasks of life and to enable safe and continuous interaction of citizens in society when outbreaks of viral pandemics such as the coronavirus. Sterilization methods, their availability in gatherings, and the efficiency of their work are among the important means to contain the spread of viruses and epidemics and enable societies to practice their activities almost naturally. Despite the effective solutions given by traditional methods of surface disinfection, modern nanotechnology has proven to be an emergent innovation to protect against viruses. On this note, recent scientific breakthroughs have highlighted the ability of nanospray technology to attach to air atoms in terms of size and time-period of existence as a sterilizer for renewed air in large areas for human gatherings. Despite the ability of this method to control the outbreak of infections, the mutation of bactericidal mechanisms presents a great issue for scientists. In recent years, science has explored a more performant approach and techniques based on a surface-resistance concept. The most emergent is the self-defensive antimicrobial known as the self-disinfection surface. It consists of the creation of a bacteria cell wall to resist the adhesion of bacteria or to kill bacteria by chemical or physical changes. Besides, plasma-mediated virus inactivation was shown as a clean, effective, and human healthy solution for surface disinfection. The purpose of this article is to deepen the discussion on the threat of traditional methods of surface disinfection and to assess the state of the art and potential solutions using emergent nanotechnology.

Keywords: surface disinfection; materials properties; standard methods; nanotechnology; COVID-19; new model

1. Introduction

The topic of viruses is well discussed and documented by scientists from different perspectives such as biologic evolution, health effect, and reactivity with surface and space. The most objective was to understand how to control their microbial viability. COVID-19 is a disease caused by a new kind of coronavirus called Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) manifested in Wuhan, Hubei, China at the end of 2019 [1]. This novel coronavirus can cause fever, respiratory failure, septic shock, and even death. Researchers believe that SARS-CoV-2 has zoonotic origin as bat coronaviruses, pangolin coronaviruses, and SARS-CoV previously discovered [2,3]. After being
transmitted to humans, this new coronavirus spreads mainly from person to person in several ways. One of the common ways of infection is contacting surfaces containing droplets from a person who is infected with the coronavirus by coughing, talking, or sneezing [4,5]. Research is still ongoing on how long the virus spends on surfaces before it loses its effectiveness. However, it was revealed that it depends on the material from which the surface is made from hours to several days [6,7]. According to the World Health Organization, cleaning and disinfecting are two effective ways to stop this virus and eliminate it from surfaces. Disinfection can be carried out either with traditional methods like liquid solutions such as sodium hypochlorite (bleach/chlorine) and alcohol at 70–90%, or ultraviolet (UV) radiation which has the capacity to destroy the DNA of the virus. However, these techniques were widely criticized by the Environmental Protection Agency opening the horizon to other innovative methods and strategies.

This paper gives a retrospective study of the standard cleaning and disinfection techniques in relation to the surface type and properties and discusses the possible use of nanotechnology to resolve several issues of the traditional methods in front of COVID virus privation.

2. Traditional Methods of Surface Decontamination: Influence of Surface Size and Type

The most important factor of surface decontamination is the surface type and properties and the substrate quality. Surface type is related to the goods material properties ((i) source (nature such as fruits and legume, hard or soft (such as a polymer)), (ii) permeability, (iii) stiffness, (iv) hydrophilicity, etc.). Besides, surface size related to the dimension of equipment and facilities is the second parameter which conditions the choice of the most suitable method. In the following, we reported the most popular methods of disinfection such as fogging, fumigation, wide-area or electrostatic spraying, and ultraviolet light techniques.

2.1. Fogging Method

The process consists of the creation of an envelope to induce a faster loss of reactivity using microbial agents. There are different fogging disinfection systems. The difference exists in the used chemical product: Sterilox hypochlorous acid, tartaric acid solution, liquid peracetic acid, alkyl amine/peracetic acid, the 7.5% of the hydrogen peroxide, and 0.2% of the chlorine dioxide solutions. This disinfection method was used in different applications, especially in the case of the human norovirus. The study done by Stein et al. [8] shows the efficacy of the fogging system using a tartaric acid solution in the pigs’ health environmental and hygiene parameters but this study should be limited to the low concentration of the tartaric acid because of its irritative effect. Krishnan et al. [9] studied the microbial activity of a dry fogging system using commercial products, whereas Krishnan et al. [10] used liquid peracetic acid (PAA). Both teams demonstrated good compatibility with electronic sensors and facilities used in laboratories, particularly hardware of computers. However, the fogging method was presented as a potential issue to other materials like steel surface.

In other fields and applications, surfaces are huger and more extended such as hospital-acquired infections. These locations are fertile zones for virus development. As a consequence, increased transmission of pathogens is noticed, from patient to patient or patient to hospital staff [11]. In fact, surfaces are more extended, spaces are more closed, and the degree risk is higher than other surfaces [12,13]. A description of hospital space disinfection with a specification of the exposure time and type of disinfection is well documented [14]. Particular attention was given to the advantages and disadvantages of the used chemical sterilant in relation to the particularity of such types of surfaces [15]. The most important was the continued evaluation of the used protocol and the strategy of fogging. In fact, Tanner et al. [16] reported that the use of hydrogen peroxide vapor in clinical surfaces provided better results compared to the steam vapor system. Ali et al. [17] clarified that the use of airborne hydrogen peroxide gives excellent results in surgical wards, single isolation rooms, and bathrooms. However, this technique is obliged to the removal of patients and has a high acquisition cost and increased room turnover time [18].
2.2. Fumigation

Fumigation is the operation of introducing a gas or a substance giving rise to a gas in the atmosphere of a partially or completely closed enclosure with a view to destroying so-called “harmful” living organisms. It was formerly the combustion of plants producing vapors charged with the active ingredients of the plant. For example, one could also produce water vapor charged with these active ingredients by boiling eucalyptus leaves in a room that we wanted to disinfect. Fumigation has been mentioned in various ancient texts; it was applied to disinfect the environments using different herbs [19]. As well as fumigation, mineral and animal products have been specified in the central nervous system (CNS) treatment fields and bacterial infections [20–22]. Zhang et al. [21] demonstrated that the combination of traditional Chinese fumigation with western medicine has a positive effect on the symptoms of diabetic peripheral neuropathy. The use of fumigation treatment in the case of vitiligo is very diffuse in Southeast Asia. However, researchers have not approved its efficacy until now. Bhatwalkar et al. [23] studied fumigation using turmeric powder, garlic peels, and other plants. This study demonstrated the efficiency of this traditional method of disinfection. Nautiyal et al. [24] and Bisht et al. [25] studied the influence of fumigation using different herbs on the reduction of airborne bacteria. Recently, several authors demonstrated the application of the grain fumigation method using plant oils to avoid insect pests [22].

2.3. Wide-Area or Electrostatic Spraying Techniques

Most surface areas are uncharged or negative. The surface disinfection using electrostatic application consists of using a disinfectant registered with the Environmental Protection Agency on the surfaces with electrostatic spraying according to Coulomb’s law [26,27]. Joshua et al. [28] demonstrated that electrostatic spraying can minimize preventable infections in large surfaces in hospital environments, improving patient experience and increasing hospital revenues. However, in order to supply more advantages over the conventional systems, the wide-area technology should be applied correctly [27]. There are many elements that can affect its efficiency: the charge/mass ratio, spraying distance, and liquid deposition efficiency target [26]. Therefore, Sasaki et al. [29] showed in their study the evolution of the factor affecting the electrostatic spraying disinfection method. Cadnum et al. [30] studied the efficiency of electrostatic spraying using a dilute sodium hypochlorite solution against the coronavirus disease pandemic. This research showed great results in the decontamination of big open areas such as airports, waiting areas, classrooms, gyms, and portable equipment.

2.4. Ultraviolet Light

The World Health Organization approved that ultraviolet (UV) is effective as a no-touch technology in the case of healthcare settings [31]. Furthermore, Wilson et al. [32] studied the ultraviolet lamps sterilization method applied to biological safety cabinets (BSC). Boyce [33] showed the importance of ultraviolet light technology in the field of disinfection to reduce contamination compared with manual techniques, especially in the medical field and hospital environment. However, this method is effective from the point of view of sterilization results and limited to closed places without the presence of people because, as known, UV has a negative effect on the human skin and eyes.

Table 1 summarizes the most used disinfectant solutions and applications.
Table 1. Examples of disinfectant solutions and applications.

| Ref | Disinfection Application | Disinfectant Actions and Remarks |
|-----|--------------------------|----------------------------------|
| [8] | Pigs' health, environmental, and hygiene parameters | Fogging a low concentrated tartaric acid solution. The ammonia concentrations are not influenced by the fogging procedure. The limitation on the tartaric acid concentration should be a maximum of 0.1% because of the negative effect on the respiratory mucosa. |
| [9] | Nosocomial and healthcare-associated infections | Fogging using garlic peel, turmeric powder, Carom seeds, and Loban. Fumigation using these plants reduces airborne bacteria. This traditional fumigation could replace the harmful and toxic chemical fumigation for healthcare environmental disinfection. |
| [10] | Electronic devices and Stainless steel, laboratory spaces, and walk-in coolers | Fogging dry fogging system (DFS) using liquid peracetic acid (PAA). The dry fogging system is an effective disinfection technology compared to formaldehyde, vaporous hydrogen peroxide, or gaseous chlorine dioxide. |
| [11] | Environmental surfaces | Sodium hypochlorite. The sodium hypochlorite is an influential disinfectant. However, the problem of direct contact is noticed to reduce healthcare-associated infection (HAIs) remains. |
| [12] | Hospital environmental, such as the surfaces of biomedical devices | Layers of graphene-based nanomaterial. Layers of graphene-based nanomaterial have several advantages. It is used to stop infections and bacteria. Unlike the known antibiotics and detergents, the nanoparticles are stable for long periods and are intoxicants. |
| [13] | Stainless steel in the food industry | Foggging disinfection with alkyl amine/peracetic acid. Due to the surface attachment and resistance, after cleaning and fogging with alkyl amine or peracetic acid, microorganisms are detected. |
| [14] | Noroviruses (NVs) in the environment | Fogging Sterilox hypochlorous acid solution (HAS). The use of these fogs is more active in the disinfection of large areas. |
| [15] | Environmental surfaces personnel, terminal, and emergency | Fogging superoxidized water (SW). The fogging system using the superoxidized water is not an expensive solution and it can be applied with the presence of persons. |
| [18] | Human norovirus (NoV) | Fogging using the hydrogen peroxide solution and the chlorine dioxide. The fogging system of the hydrogen peroxide promising virucidal activity, however, fogged chlorine dioxide-surfactant-based product is uniformly delivered and effectively used for the application of closed areas NoV disinfection, allowing the disinfection using the saturation of the environment air which leads to sterilizes all surfaces. |
| [28] | Hospital environmental surfaces | Electrostatic spraying Electrostatic disinfection. The disinfection methods including wipes, spray, fogging, and UV lighting may be expensive for daily use, but the electrostatic disinfection systems present a reliable with acceptable costs in the environmental surface disinfection. |
| [29] | Coronavirus (COVID-19) | Ultraviolet (UV). The UV technology is efficacious; however, it has a bad effect on the human body in the case of repetitive exposure. |
| [30] | Biological safety cabinets (BSC) | Ultraviolet (UV). The radiation output of the UV should not be less than 40 mW/cm² at a wavelength of 254 nm to kill microorganisms. Ultraviolet (UV) lamps are not recommended in BSCs because it should be stopped when there is someone in the room to protect eyes and skin human from the exposure to the UV light. |

3. Reproach and Complaint of EPA (Environmental Protection Agency)

As reported in [34], the Environmental Protection Agency (EPA) has different reasons against fogging/misting methods of application, specifically that they may not be adequately effective. Indeed, disinfection product applications by spraying, sponging, wiping, or mopping are more efficient than fogging/misting applications, which result in much smaller particle sizes and different surface coverage characteristics. Additionally, precleaning in the presence of soil contamination and potential reaction with the absorption of the active ingredient for different surfaces with variations in the humidity and the temperature is important, which develops the distribution and efficacy of the product. The standard methods are more effective in the distribution on the surface than the area treatment by fogging.
4. Innovation in Surface Disinfection Method

As the reactivity of microorganisms varies from most resistant to less resistant, besides the reproach of the EPA, more efficient, novel, and environmentally friendly tools and techniques are required for virus inactivation. This issue was clearly shown with the appearance of the novel and specific virus SARS-CoV-2. This virus, 100–300 nm in size and comprising nucleic materials surrounded by proteins and enveloped by a rich lipid layer, can survive on different surfaces and places such as on metal, glass, wood, textiles, etc., for several hours to days [2,4,5]. It is characterized also by a virus breed mutation in relation to the environmental conditions and exposed surface [35]. Therefore, innovation in the surface disinfection method can prevent infection and the spread of disease. Modern technology specific to the disinfection of environmental surfaces in hospitals and healthcare staff is discussed.

4.1. Antimicrobial Spray Nanocoating

4.1.1. Principle

Antimicrobial spray nanocoating was recently developed to control surface reactivity and properties. Dray nanospray is one of the most innovative technologies and has many advantages in terms of its ability to produce nanoparticles with much smaller droplets and a narrow area distribution [36]. Nanospray drying offers high stability to control particle size and morphology by optimizing the process parameters and nanoparticle characteristics. Spray drying is able to produce different forms of particle shapes [37]. Nanospray drying allows volume reduction, defined particle size, changing chemical, and physical properties with chemical and biological stability and high specific surface. Additionally, nanospray drying offers easy dosage administering and handling. It was initially utilized in the pharmaceutical field. Table 2 shows examples of FDA-approved medicine using nanospray drying technology as a preparation method.

| Production Company | Product | Disease | Materials | Company | FDA Approval |
|--------------------|---------|---------|-----------|---------|--------------|
| Prograf Tacrolimus  | Immunosuppressant (prevents organ rejection) | HPMC | Astellas Pharma | 1994 |
| Exubera Insulin    | Diabetes | Mannitol, glycine, sodium citrate | Pfizer/Nektar | 2006 |
| Intelect Etravirine | HIV medicine | HPMC | Janssen | 2008 |
| Zortress Evololimus | Immunosuppressant (prevents organ rejection) | HPMC | Janssen | 2010 |
| Aridol/Osmohale, Bronchitol | - | Asthma/Cystic fibrosis, Bronchitis | Mannitol | Pharmaxis | 2010 |
| TOBI Podhaler Tobramycin | Inhalation therapy | DSPC, calcium chloride, sulfuric acid | Novartis | 2013 |
| Raplixa - | - | Bleeding control during surgery | Fibrinogen/Thrombin | Novartis Laboratories | 2016 |

The nanospray drying process consists of six fundamental steps [45–48]. The first stage is heating the inlet air to the desired temperature not to exceed 220 °C. The second stage is droplet formation using a two-fluid nozzle or ultrasonic spray head. Before the collection of the particle using cyclone technology or electrostatic particle collector, the drying step between drying gas and sample droplets is important. Then, the finest particles were collected to protect the user and environment using an outlet filter. Finally, was drying gas delivered by aspirator or with compressed air. A piezoelectric actuator vibrates a small replaceable spray cap, containing nanometric holes, to generate droplets. The latter leads to rapid vertical movement of the spray mesh, ejecting many droplets in size accurately through the holes in the drying chamber. The size of the droplets depends on the size of the holes and the physicochemical characteristic of the disinfectant. The flow of concurrent drying gas directs the
particles to the electrostatic particle collector. The electrostatic particle collector can capture nanometric particles (<1 μm) with separation efficiency. The particles are gently removed from the inner surface of the collecting electrode cylinder using the particle scraper [49–51]. Figure 1 shows a schematic representation of the nanospray dryer principle.

The pore size is in the order of nanometers distributed on the spherical surface of the nanosprayed particle powder. The nanoparticles are produced with an irregular form and spherical shape. There is a slight difference.

Figure 1. Schematic representation of the drying nanospray principle.

The sizes of the particles formed through encapsulation are nano (<1 μm) [52–55] and known as nanocapsules [56]. The smaller the particles, the better the solubility of the encapsulated liquids. The droplets obtained at the nanoscale lead to an increase in the volume distribution in the surface, which generally occurs by reducing the size of the drops, thereby increasing the particles’ efficiency [57]. The cost reduces by using nanodrop sterilization instead of other sprayers [58]. There are important input parameters identified: (i) spray mesh size, (ii) spray rate intensity, (iii) solid concentration, (iv) polymer and surfactant concentrations, (v) drying gas inlet temperature, (vi) solvent type and (vii) drying gas flow rate. On the other hand, there are important output parameters: (i) particle size, (ii) product yield, (iii) amount particles produced, (iv) particle morphology, (v) bioactive loading, (vi) controlled release profile, (vii) encapsulation efficiency and stability.

4.1.2. Possible Exploitation of Nanocoating to Protect against COVID-19

In the last decimal, many laboratories and researchers have focused on the development of antiviral nanocoatings. As innovation, they tested nanopowder technology to create a more stable layer and ensure a large surface area compared to the volume ratio: a small number of particles induces an efficient antiviral surface [59–61]. To visualize the morphology of the nanopowder, observations of the powder with a resolution smaller than 1 nm and high magnification should be made [62]. The morphology of the nanosprayed powder is a spherical shape with a porous surface. The pore size of the powder with a resolution smaller than 1 nm and high magnification should be made [62].
between the nanoparticle sizes [63]. To measure the size of the nanosprayed powder, there are different instruments such as dynamic and static light scattering ((DLS) and (SLS)), gravitational settling and centrifugation (GSC), laser-induced breakdown detection (LIBD), and laser particle analyzer (LPA) [58,64,65]. Using the old nanospray dryer classic instrument, the dried particle size is in the range of 0.3 μm to 5 μm [66–69]. Indeed, using the new concept mechanical technology method can create powders in the nanometric size range with stable distributions and high formulation yields. This novel spray produces and collects submicron particles from a disinfectant solution. The dried particle size is in the range of the 285 nm to 999 nm [70].

Many different types of nanoparticles have been shown to be effective at inactivating viruses, including coronaviruses such as SARS-CoV-2. For example, nanoscale zinc oxide, cuprous oxide, silver, copper iodide, polymer, titanium oxide, gold on silica, and quaternary ammonium cations (quats) have all shown promise [71–75]. The choice of the sprayed nanoparticle protocol and methodology is depending on the application field. For example, last semester, researchers from Hong Kong University of Science and Technology developed a nanocapsule formed with heat-sensitive polymers that contain disinfectants [76]. This material is known by multilevel antibacterial polymer MAP-1. It is prepared from polymer encapsulated chlorine dioxide [77]. The polymer releases the biocides at the sites of contamination when warmed by human contact [78]. It was used in public places such as shopping malls, schools, and buses as a surface sterilization solution against COVID-19.

Another innovative solution used a combination of nanoactive elements formed by positively charged silver nanoparticles sprayed on surfaces to create a low surface energy nanocoating [79]. The stages of the formation of these elements under ambient conditions were widely described in [80]. The mechanism of bacterial inactivation described in Figure 2 is based on the interaction of Ag nanoparticles with the inside and the outside of the cell membrane rich in sulfur containing amino acids to inhibit microorganism activities. Despite that this nanocoating was initially developed to protect against bacteria, fungi, and algae, it was tested to be effective against COVID-19 since February 2020 on many types of materials such as metals and plastics [81]. More than 99% of antiviral efficiency was noticed in 2 h of contact in different places (airports, schools, and markets). However, more tests of performance are in development to extend the use of this method for other materials.

1: Interference with replication
2: Interaction with various metabolism
3: Interaction with membranes
4: Interference with cell wall

Figure 2. Schematic representation of the bacterial inactivation mechanisms using silver nanoparticle.

4.2. Self-Disinfection Surface

In critical areas like hospitals and healthcare facilities, surfaces are considered clean if 50% of the surfaces are disinfected and hospital staff members wash their hands for 15 s [82]. Therefore, the protocol of classical methods of sterilization is not always required [83]. Recently, researchers developed new technology able to kill and disable microbes in contact [84–86]. The most emergent is the self-defensive antimicrobial known as the self-disinfection surface. It consists of the creation of a bacteria cell wall to resist the adhesion of bacteria or to kill bacteria by chemical or physical changes [87–91]. This technique is classified in three categories: surface resisting the bacteria attachment (Figure 3a) using the photactivation process for example [90], surface leaching antibacterial agents (Figure 3b) called intrinsically antimicrobial ability [91], and surface killing or delivery bacteria by contact using antimicrobial loading (Figure 3c), based on the coating technology [92] or incorporation process [93]. The mechanisms of surface reaction were detailed in [94] and illustrated in Figure 4.
However, this technique is not standard and depends on the materials’ family, since each material has its own way of reacting according to its properties [95]. The most important functional materials are photoactive building monocrystals (CuInZn4S6) [96], both TiO2 and SiO2 nanocoatings [97–99], antimicrobial peptide substance [100], and membrane-active polycations [101].

Plasma generation is attributed to the creation of anodized gas which contains reactive chemical elements such as electrons, ions, and charged species [106]. Despite that it was discovered in 1927 as the fourth fundamental state of the matter, the microbicidal properties of plasma were really explored only in the last 15 years [107]. Several studies have investigated the effect of plasma treatment on the inactivation of both enveloped and nonenveloped viruses, bacteria, and fungi [108–110]. It was reported that the applicability of plasma technology in surface disinfection is potentially wide-ranging. However, nitrogen-gas plasma and UV radiation have the most effective impact on viruses and about a six-log reduction/inactivation performance for bacteria. Other techniques used innovative methods by radiofrequency plasma treatment using an Ar/O2 gas mixture [111]. They concluded that plasma can not only disinfect surfaces but also degrade toxins. The mechanisms of degradation are directly

4.3. Plasma-Mediated Virus Inactivation

Figure 3. (a–c) Three categories of self-disinfection surfaces [93].

Figure 4. Mechanisms of antimicrobial surface activation [94].

Besides, few pieces of research have successfully clarified the long-term efficacy, durability, and mechanical stability of the antiadhesive action in relation to the environmental conditions, the scalability of production, and the real cost of these settings when we talk about large areas [102–105].
related to the used gases as well as the method used to generate plasma and the target microorganism. However, the exact mode of the plasma functionality remains largely unexplored. More innovative devices were developed for the disinfection of fruits and vegetables using atmospheric pressure plasma, others for the sterilization of medical instruments using gamma-ray treatment [112]. However, induced changes in the properties of the materials were noticed. A protocol of evaluation of each sterilization method should be developed specifically to the corresponding application with respect to the relative norms. Despite that plasma-mediated virus inactivation is a relatively young field of research, encouraging results were reported in the treatment of the viral pandemic COVID-19 using cold plasma treatment is known as a reactive oxygen and/or nitrogen species [113,114].

4.4. Modern Technology for Healthcare Environment and Surface

Considered as the highest exposed environment to microorganisms, healthcare workers and relative equipment and devices are suspected to be what is called high-level disinfection [115]. Therefore, modern technology was developed in recent years that investigated basic knowledge and studied cases [116]. The objective was to protect the staff and to prevent the transmission of infectious agents. Their use was associated with an improvement in the cleaning and disinfection of high touch surfaces with a specific protocol and guidelines taking into account (i) the potential of the environmental surfaces to transmit infection, (ii) mode and duration of contact, and (iii) toxicologic risk assessment [117].

Jensen described the use of ultraviolet germicidal irradiation as a disinfection method that kills airborne viruses using short-wavelength ultraviolet and by destroying its AND. Satisfying results were reported in hospitals in Italy in relation to the new COVID-19 [118]. Weber et al. explained the use of touchless cleaning robots as an innovative method that is clean and effective in decreasing microbial surface contamination [119]. However, complex surfaces may be incompletely targeted by robot technology. Therefore, traditional methods of sterilization are regularly completed to disinfect healthcare staff clothes, equipment, and devices.

5. New Framework for Prevention, Diagnostic, and Monitoring of Surface Disinfection

Based on our review work, it is clear that surface disinfection depends on several parameters and is widely used for cleaning, disinfection, and sterilization. Thanks to innovative technologies, protocols, and creativity, new methods have been developed with a continued evolution to improve performance. Figure 5 illustrates our proposed new framework with possible interaction and influences.

![Figure 5. New model of surface disinfection methods, techniques and possible interactions and evolution.](image-url)
6. Conclusions

From this review study, the following conclusions are reported:

- Virus or bacteria disinfection is widely influenced by the type, size, and properties of surfaces which are considered as the major factor contributing to the dissipation of an epidemic.
- The choice of the disinfection technique is based on Multiphysics rules. Traditional techniques such as fogging, Fumigation, wide-area or electrostatic spraying, and ultraviolet light techniques are still used to conserve equipment and surface from viruses. However, many approaches specified by the Environmental Protection Agency narrow their evolution despite the progress of sterilized solution and light technology.
- An antimicrobial spray nanocoating was introduced as an emergent technology to produce efficient and inhalable nanopowder pulverization for healthy surfaces and presented as possible innovative methods to protect against COVID-19.
- Relatively, self-disinfection surfaces were recently developed using chemical and physical modifications of the surface to kill or eject microorganisms. As there are several points to be more standard and well-controlled, this technique is considered a step forward to the future of the controlling protocol of disinfection.
- Plasma-mediated virus inactivation was in higher microorganism inactivation potential. Given the fact that this technology is clean, effective, and human friendly, it can become a promising solution when related to modern technology.
- A new framework for prevention, diagnostic, and monitoring of surface disinfection was proposed.

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