Chapter

Antiviral Strategies in the Treatment of Viral Infections in Humans and Animals: Surface and Space Disinfection Strategies

Shouguo Wang, Bin Yan and Li Song

Abstract

The 2019 coronavirus (COVID-19) epidemic is rampant, making people's awareness of virus elimination and prevention gradually increase, and giving more attention to the cleanliness of the indoor air environment and the use of goods. According to the World Health Organization (WHO) estimates, the annual global influenza cases can reach 1 billion, including 3 million to 5 million severe cases, and the number of deaths from influenza-related respiratory diseases recorded is as high as 290,000 to 650,000. The virus is generally transmitted through respiratory droplet transmission, airborne transmission, and contact transmission. For most infectious diseases, disinfection, isolation, and personal protection remain the most effective means, especially in the prevention and control of influenza, intestinal infectious diseases, contact-transmitted diseases, bloodborne diseases, and sexually transmitted diseases, which are most effective in spring, such as in 2019 coronavirus, severe acute respiratory syndrome (SARS), Middle East respiratory syndrome (MERS), influenza, and other. In respiratory infectious diseases, early disinfection is an important means of prevention and control; viruses can also be transmitted by contact and through a variety of ways, which occur in indoor spaces and on the surfaces of indoor objects. As a result, many different methods of disinfection have been conducted for indoor spaces and surfaces of objects.

Keywords: viruses, surface sterilization, space sterilization, physical disinfection, chemical disinfection, comprehensive disinfection

1. Introduction

Disinfection is an effective measure to cut off the transmission of infectious diseases. Most countries specify the concentration of bacterial and fungal colonies, only Korea specifies the total number of colonies, the U.S. Food and Drug Administration (FDA) does not provide specific limits, and China requires that "the logarithm of the extinction of natural bacteria in the air is ≥1.00." The choice of disinfection method depends not only on the disinfection product itself and external controllable factors such as temperature, concentration, exposure time, etc., but also on the subjective will of the user. Physical, chemical, and other disinfection methods can be used to eliminate bacteria and viruses present in space and on surfaces with objects, such as temperature, electrostatic adsorption, air laminar flow purification, filtration, ultraviolet (UV), photocatalytic, plasma, and other physical methods, chlorine dioxide, sodium hypochlorite, hydrogen peroxide, and peroxyacetic acid, and other common disinfection means such as ozone and herbal disinfection (**Table 1**) [1]. Different disinfection methods differ in their application forms and inactivation effects depending on the environment in which they are used. In addition, in terms of the development path of the disinfection technology itself, it can be divided into static and dynamic disinfection technologies based on whether it supports human-machine coexistence as a basic feature. Static disinfection technology is widely used in the final disinfection and preventive disinfection process, which means that disinfection is carried out in an unoccupied environment and personnel must leave the site before entering the disinfection state, often using ultraviolet (UV) lamp disinfection, ozone disinfection, hydrogen peroxide spray disinfection, and peroxyacetic acid fumigation; dynamic disinfection technology is widely used in all types of environments at any time of disinfection, which means that disinfection can be carried out in a human environment, so disinfection staff do not need to leave the site. Dynamic disinfection technologies are widely used in all types of environments to disinfect at any time. Air disinfection can weaken the airborne capacity and transmission of viruses, while surface disinfection can eliminate the source of infection and cut off the transmission pathway.

This chapter will systematically discuss the principles and advantages of the above-mentioned antiviral methods and compare them with contemporary environmentally friendly and economical materials to propose viable strategies for making surface and space disinfection more efficient and economical, including novel products such as wearable protective devices.

2. Physical disinfection

Physical disinfection refers to the use of physical methods such as inactivation or destruction of microbial structures through heating, mechanical damage, irradiation, etc., to achieve disinfection effects. The common disinfection used for air and object surfaces can be categorized as ventilation, heating disinfection, plasma disinfection, ozone disinfection, ultraviolet (UV) disinfection, and other disinfection methods, which are described below according to the different subjects used for disinfection.

2.1 Ventilation and disinfection

The function of ventilation is to make the air circulate and take away some of the bacteria in the air or blow away the bacteria attached to the surface of objects. In schools, libraries, and other public places, as well as in the daily life of families, this disinfection method is preferred. In hospitals, treatment rooms, operating rooms, and other environments, ventilation plus air disinfection can ensure the quality of indoor disinfection.

DOI: http://dx.doi.org/10.5772/intechopen.112501

Disinfection category	**Heating**	**Plasma**	**Ozone**	**Ultraviolet**	**Adsorption**	**Negative ions**	**Photocatalysis**	**Chemical reagents**
Principle	High Temperature Inactivation	High Energy Ion Breakdown	Oxidation	Radiation denaturation	Filter adsorption	Oxidation decomposition	Hydroxyl radical decomposition	Reaction product abatement
Mode of action	Machine	Machine	Ozone release	Irradiation	Passive adsorption	Machine	Machine	Wipe/Spray
Disinfection range	Object table/air	Object table/air	Air	Object surface/ air	Air	Air	Air	Object table/air
Disinfection efficiency	Low	High	High	High	Low	Low	High	High
Harmful reagents	/	/	/	/	/	/	/	√
Harmful rays	/	/	/	√	/	/	/	/
Harmful gases	/	/	√	/	/	√	/	/

Table 1.
Common disinfection techniques and comparison.

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2.2 Heating and disinfection

According to the characteristics of COVID-19 and other viruses that are not heat-resistant, high temperatures can be used to inactivate them. The principle is: in the indoor environment, it is not possible to heat the environment as a whole to the virus inactivation temperature (56°C), but continuous heating of a small amount of air above 100°C is still easy to do, however in the environment above 100°C virus life will be greatly reduced, the temperature is high to a certain extent, and the new crown-like virus may be in an "instant" manner burned to death. High-temperature conditions will also reduce the humidity of the air, so that the droplets wrapped in the virus periphery undergo moisture evaporation, which also deprives the virus of survival conditions. Heating is mostly done with a specific electric heater, so that the ambient air enters through the entrance of the electric heater, passes through the heater at 200°C or even higher, and then exits, during which the virus is inactivated by the high temperature. This process of heating and inactivation is continuous. As shown in **Figure 1** below:

And the electric heater that can achieve the above ability can be mainly divided into (1) a resistance wire heater (heating wire surface temperature up to 1000°C or more); (2) positive temperature coefficient (PTC) ceramic heater (heater surface temperature is generally 275°C); and (3) any other high surface temperature heat conduction-type electric heater. Theoretically, the heater can kill all kinds of germs, especially for the temperature sensitive virus for example the 2019 coronavirus. However, the specific sterilization time, power, environment, and space adapted to further research are needed. Such as a home electric hair dryer whose internal temperature can also reach more than 56°, can produce dry hot air, and also has the potential and ability to sterilize the new coronavirus, it needs a certain role time. Later, a small home-type high-temperature sterilizer can be developed based on the portable characteristics of the hair dryer. In addition, most nonspore bacilli are 80 ~ 100°C under a few minutes almost all dead, 70°C need 10 ~ 15 min to kill, and 60°C must be more than 30 min to be killed. The spores of mold usually 86 ~ 88°C heated for 30 min can die. Therefore, with the help of an indoor furnace, the incineration method, the dry baking method, as well as high-energy infrared and other high-temperature methods it is possible to kill bacterial germ cells, to achieve a sterilization effect.

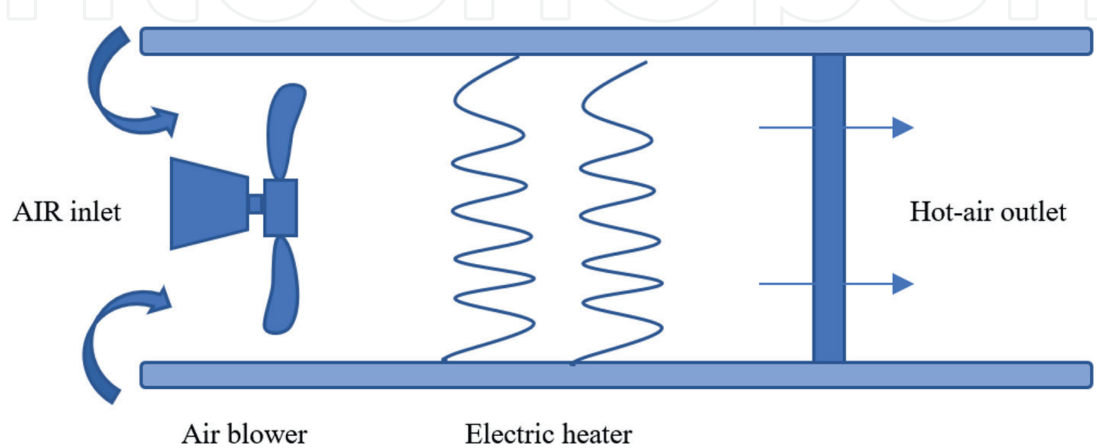

Figure 1.
Electric heating wire channel sterilization.

High-temperature disinfection is a commonly used means of disinfection for medical devices. Medical devices can be classified as high-, medium-, and low-risk medical devices based on their risk of causing infection in use. High-risk medical devices must be sterilized before use, medium-risk devices should be disinfected at a high or medium level before use, and low-risk medical devices should be disinfected at a medium or low level before use or kept clean daily. One study treated duodenoscopes with three different levels of disinfection and found no significant difference between the three groups mentioned above [2]. Therefore, it is sufficient to disinfect medical devices and equipment according to the level in which they are located, without the need to overdisinfect and cause a waste of resources. Among them, medical devices that are resistant to moisture, heat, and reusability should be preferred to autoclaving; glass devices, oils, and dry powders are generally selected for dry heat sterilization; and those that are not resistant to heat or moisture are selected for low-temperature sterilization.

Boiling disinfection is a frequently used and effective method for disinfecting the surface of hospital objects, which can cause most of the nonbudding pathogenic microorganisms in the objects to die rapidly in boiling water at 100°C. Most of the budding spores can be killed in 15–30 min of boiling, and all pathogens can be eliminated by boiling for 1–2 h. However, when the object is exposed to hot and humid air, it will lose its antifouling properties, resulting in secondary contamination [3]. Various metals, glass equipment, and clothing can be disinfected by boiling. Steam disinfection is a method of disinfection using water vapor at about 100°C under atmospheric pressure and is mainly used for the disinfection of hospital aids, such as mattresses, bedding, and bedsheets.

2.3 Plasma disinfection

In 1996, Laroussi, an American scientist, found that atmospheric pressure low-temperature plasma has a good killing effect on *Pseudomonas aeruginosa*, which is the earliest report on sterilization by atmospheric pressure low-temperature plasma. Plasma air sterilizers can significantly reduce the infection rate in surgical ports compared to UV and chemical disinfection. Plasma sterilization also decomposes polymeric toxic organic compounds such as formaldehyde and smoke and converts them into nontoxic, odorless inorganic substances such as carbon and water, which are not harmful to humans or medical equipment. This technology has been shown to inactivate a wide range of microorganisms such as bacteria, fungi, viruses, and spores, and has received increasing attention due to the above-mentioned efficient disinfection capabilities and environmental friendliness [4]. The principle of atmospheric pressure low-temperature plasma sterilization is to achieve rapid killing of bacteria and viruses using the compound action of electrons, ions, photons, and free radicals contained in the plasma. Low-temperature plasma sterilization can not only kill germs in space but also achieve rapid sterilization of the surface of the object, as well as the surface of human skin. Because its unique advantages have attracted the attention of more and more researchers, the killing effect on microorganisms is also heavily studied and applied. The plasma channel made using atmospheric pressure low-temperature cold plasma technology (such as medium blocking plasma discharge dielectric barrier discharge (DBD)), as shown in **Figure 2**, and by combining other machine materials, such as combining fans and purification filter materials, can make air purification and sterilization products such as circulating air plasma sterilizer (**Figure 3**). The machine is mostly used for preventive disinfection in crowded

Figure 2.
Atmospheric pressure low-temperature cold plasma discharge channel.

Figure 3.
Circulating air plasma sterilizer.

places such as operating rooms, fever clinics, intensive care units, etc. The common equipment is contact, and the positive and negative ions in the interface capture microorganisms to kill them and achieve air disinfection. Low-temperature plasma air disinfection machines can inactivate bacteria and viruses in artificially generated aerosols very well, with purification efficiencies (removal rates) of 99.98, 99.98, and 99.95% for *Staphylococcus aureus*, *Micrococcus garcinia*, and ΦX174 phage aerosols. However, due to the complexity of the machine system, problems, such as the whole machine not working, plasma not working, fan not working, small airflow at the outlet, machine not working according to the set time, or remote control not responding, often occur in daily use. In daily maintenance, it is necessary to regularly maintain and repair its filter motor, to improve the quality of equipment operation and ensure the safe and effective operation of the air disinfection machine and provide a strong guarantee for clinical diagnosis and treatment services.

Atmospheric pressure low-temperature cold plasma beam can eliminate pathogenic bacteria such as *Escherichia coli*, *Candida albicans*, *Staphylococcus aureus*, and *Bacillus subtilis* attached to different materials (**Figure 4**).

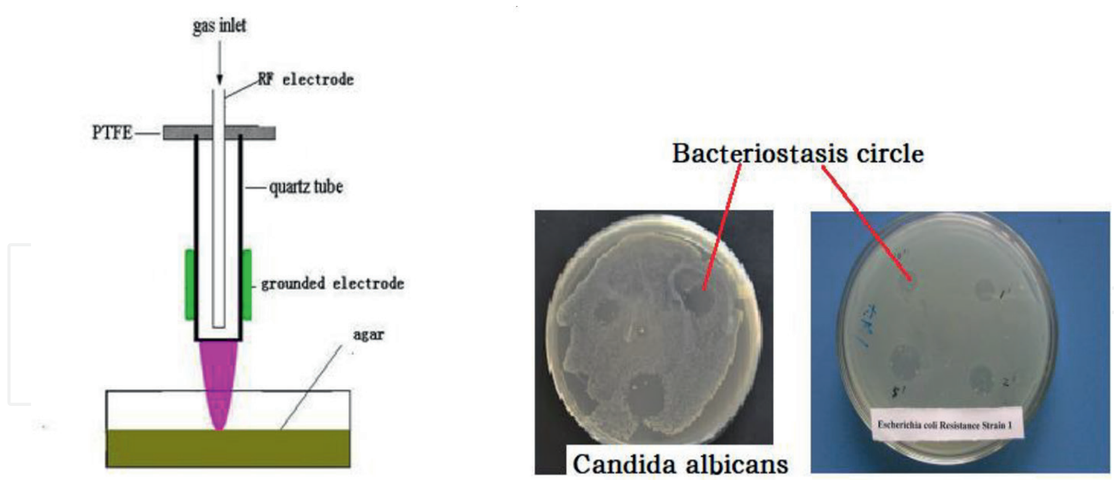

Figure 4.
Experiment of atmospheric pressure plasma killing bacteria.

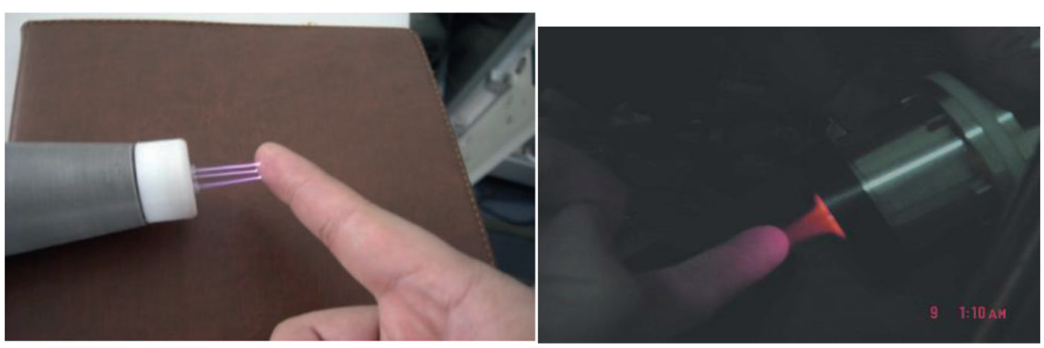

Figure 5.
Atmospheric pressure plasma beam can interact with human skin.

In a study using helium and argon plasma beams as working gases, it was found that atmospheric pressure low-temperature plasma beams sterilize quickly, killing germs on the surface of objects quickly and without damaging human skin within 1–2 min (**Figure 5**) [5].

Meanwhile, more and more researchers have successfully discovered that atmospheric pressure low-temperature plasma can act on Gram-positive bacteria, Gram-negative bacteria, spores, microbial biofilms, fungi, viruses, etc., and have a good killing effect on all of them, unveiling a new picture as physical sterilization of human skin and object surfaces (**Figure 6**).

Atmospheric air plasma can also treat *Escherichia coli*, *Staphylococcus aureus*, yeast, and phage ΦX174 attached to different materials, the survival number of microorganisms attached to the surface of the treated materials was significantly reduced, the surface of the bacteria was broken after 10–25 s of discharge treatment and fragments could be seen under the microscope, and after 59–90 s of treatment, the survival number of bacteria was reduced by at least 5. The mechanism is the hypothesis of cell membrane fragmentation due to reactive oxygen species (ROS) [6]. The accumulation of experiments on the disinfection of microorganisms on the surface of objects by low-temperature plasma gradually unveiled the wide application of atmospheric pressure low-temperature plasma sterilization technology. *In vitro*, the action of

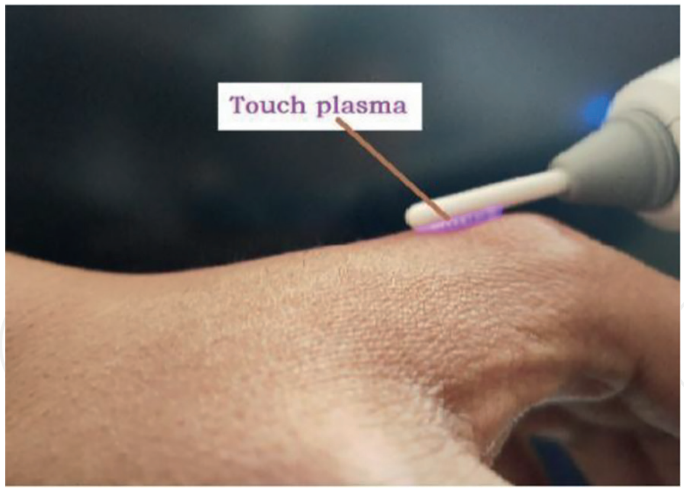

Figure 6.
A plasma in touch with human skin.

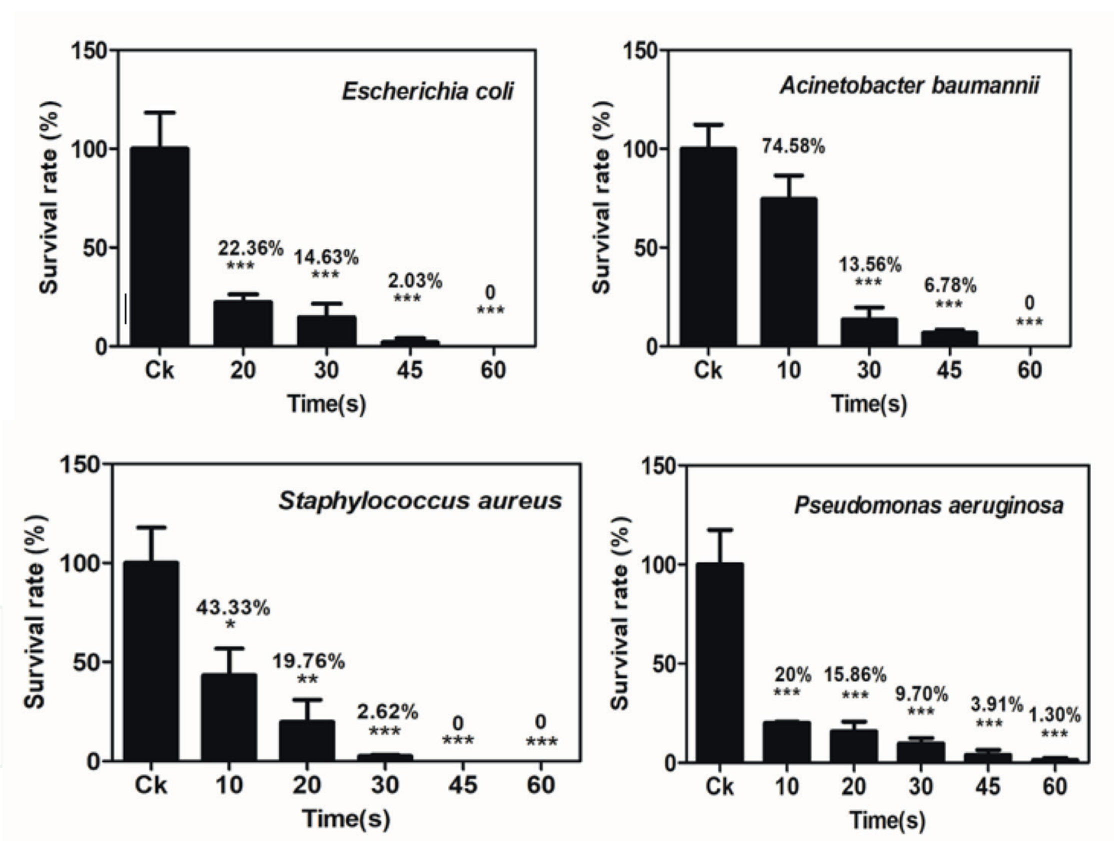

Figure 7.
The remarkable killing effects on common bacteria and fungi in the clinic.

pathogenic microorganisms on the surface of skin wounds using a low-temperature cold plasma beam obtained the following sterilization effects (**Figure** 7):

2.4 Ozone disinfection

Commonly used ozone generators are generated by atmospheric pressure low-temperature plasma discharge, generally using a medium to block the plasma discharge can generate ozone, its generation principle is shown in **Figure 8** (left), and **Figure 8** (right) for indoor space with a small ozone generator photograph.

The mechanism of action of ozone disinfection (**Figure 9**) is that ozone can diffuse into the surface of microbial membranes or protein shells for rapid oxidation reactions with pathogens, degrading biofilm and shell structures, and leading to loss of cytoplasm and intershell substrates. The ozone that penetrates the membrane and shell and the reactive oxygen species it generates can further attack the genetic material DNA or RNA, disrupting the structure of bacteria and viruses leading to the destruction of genetic material and inactivation of coenzymes, thus achieving disinfection [7].

Compared to chlorinated disinfectants, ozone has a shorter reaction time and a lower regeneration rate of microorganisms, and it can decompose itself into oxygen without residual contamination. Therefore, it is commonly used for air disinfection in large workshops and laboratories. However, excessive ozone can not only remove organic micro-pollutants, but also corrode pipeline equipment, and incomplete oxidation reaction with dissolved organic micro-pollutants will produce toxic and harmful disinfection by-products, thus causing risks to the surrounding environment and human body. Therefore, the optimization of ozone disinfection technology and the development of the ozone co-disinfection process will also be an important development direction in the future.

The use of ozone treatment reported by B. Clavo et al. [8] was able to provide good inactivation of personal protective gear contaminated with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2 virus) after only 30 s treatment when the volume fraction of ozone reached $10{,}000 \times 10^{-6}$.

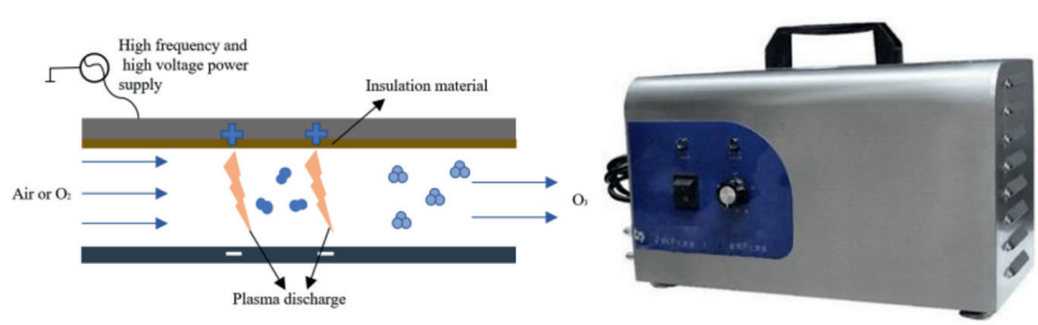

Figure 8.
Generation principle (lift) ozone generator (right).

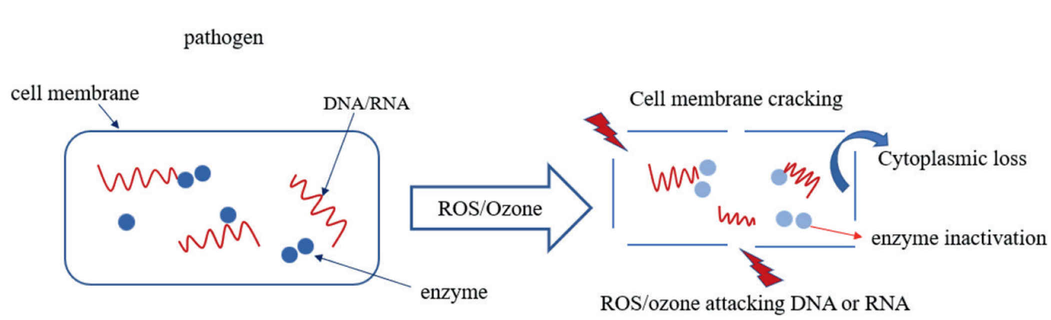

Figure 9.
Mechanism of ozone action.

2.5 UV disinfection

Germicidal disinfection by ultraviolet C (UVC) shows that the use of UVC can damage the molecular structure of DNA (deoxyribonucleic acid) or RNA (ribonucleic acid) in the cells of microbial organisms, resulting in growth cell death and (or) regenerative cell death to achieve the effect of germicidal disinfection. The action of UV on nucleic acids can lead to bond and strand breaks, interstrand cross-linking, and formation of photochemical products, which alter the biological activity of DNA and make the microorganism itself unable to replicate and proliferate, and this UV damage is also lethal [9].

In an unoccupied environment, UV disinfection is currently the most commonly used physical disinfection method in medical units and the most used disinfection instrument in households since the outbreak of the new crown-like virus. Since viruses absorb the largest amount of photons at a wavelength of 260 nm, 260 nm UV is generally chosen to destroy the nucleic acids and envelope proteins of viruses and microorganisms to kill microorganisms. However, its disinfection effect is also easily affected by the temperature and humidity of the surrounding environment. When the room temperature is higher than 40°C, lower than 20°C, or the humidity is greater than 60%, it is necessary to extend the irradiation time of the UV lamp. Usually, UV is used in combination with other substances. Common joint processes include UV + H_2O_2, UV + H_2O_2 + O_3, UV + TiO_2, UV+ negative ions, air filtration systems, etc., work together to kill pathogenic microorganisms in the air, and the joint use can achieve better disinfection effects. Of course, the final effect of UV sterilization is related to the intensity (power) of UV irradiation, irradiation time, and space size.

The germicidal effect is determined by the dose of irradiation received by the microorganism, and also by the output energy of the UVC, which is related to the type of lamp, light intensity, and time of use; as the lamp ages, it will lose 30–50% of its intensity. UV irradiation dose is the amount of specific wavelength UV needed to achieve a certain bacterial inactivation rate: the higher the germicidal efficiency required, the greater the required irradiation dose.

Disinfection of indoor air can be carried out by the indirect irradiation method and the direct irradiation method. Among them, the indirect irradiation method is preferred with a high-intensity UV air disinfector, as it not only has a reliable disinfection effect and can be used during indoor activities, generally turning on the disinfection 30 min can reach qualified disinfection level; the direct irradiation method in indoor unoccupied conditions can take the UV lamp of the hanging type or mobile direct irradiation. When using indoor suspended UV disinfection or indoor installation of UV disinfection lamp (30 W UV lamp), the intensity at 1.0 m > 70 uW/cm^2 number of not less than 1.5 W per cubic meter on average irradiation time of not less than 30 min is recorded.

While using ultraviolet disinfection, it should be noted that:

1. In the process of use, the surface of the UV lamp should be kept clean, generally wiped once every 2 weeks with an alcoholic cotton ball, and the surface of the lamp should be wiped at any time when dust and oil are found.

2. When using UV lamps to disinfect indoor air, the room should be kept clean and dry to reduce dust and water mist, and the irradiation time should be extended

appropriately when the temperature is lower than 20°C or higher than 40°C and the relative humidity is greater than 60%.

3. When disinfecting the surface of articles with UV light, the irradiated surface should be exposed to direct UV light and should reach a sufficient dose of irradiation.

4. When using UV light source, we shall not make the UV light source irradiate people to avoid causing injury;

5. The UV intensity meter is calibrated at least once a year.

2.6 Other physical disinfection

In addition to the physical disinfection methods mentioned above, high-pressure electrostatic adsorption, negative ion disinfection, ultrasound sterilization, microwave sterilization, ionizing radiation sterilization such as X-rays and γ-rays, electron beam sterilization and other sterilization methods are also common in the food industry, medical devices, and pharmaceutical industry. High-pressure electrostatic adsorption air disinfection is also mostly used in closed medical operation areas such as emergency surgery or outpatient drug change rooms, but the effect and application of high-pressure electrostatic adsorption on SARS-CoV-2 are to be confirmed by further clinical studies. These methods include thorough sterilization and high health safety, but the radiation sources are generally large and can only be installed and used in fixed settings.

In addition, nanometer antibacterial material is a new class of healthcare antibacterial materials developed in recent years and is the focus of nanotechnology and antibacterial technology research. Nanomaterials have a large specific surface, bond mismatch, and many active centers so nanomaterials have a strong electrical capture ability, which can strongly attract the sulfhydryl groups of proteases in bacteria, and quickly combine to make the bacterial genetic enzymes inactive, resulting in the death of bacteria.

Nanometer antibacterial products continue to enter people's daily life. For example, nano antibacterial thermal underwear and antibacterial shoes and socks are now available in the market. Adding nanoparticles to chemical fiber products and textiles also has the effect of deodorizing and sterilizing property, adding silver nanoparticles to socks can remove foot odor; adding silver nanoparticles to medical gauze has the sterilizing effect.

3. Chemical disinfection

Chemical disinfection is the use of chemical disinfectants to act on microorganisms and pathogens to denature their proteins and cause them to lose their normal function and die. The disinfectants used in air and surface disinfection can be divided into four categories: chlorinated disinfectants, nonchlorinated disinfectants and chemical surfactants, and plant disinfectants. In the use of chemical disinfectants, it is necessary to consider not only the impact of the type of chemical disinfectant, the dose and ratio used, the duration of action, pH, temperature, and other factors on the efficiency of virus inactivation but also the impact on human health.

3.1 Chlorinated disinfectants

When used for air disinfection, commonly used chlorine-containing chemical disinfectants include over 84 disinfectants, bleach, chlorine-containing effervescent tablets, hypochlorous acid, chlorine dioxide, and other reagents in the form of liquid or spray for disinfection operations of ambient air. Among them, spray disinfection refers to spraying the disinfectant through mechanical force or any other means of action, so that the disinfectant forms a water mist of fine droplets or atomized into aerosols, and the object surface or air disinfection way is the site of environmental disinfection which is a commonly used disinfection method. Chlorine dioxide performs the functions of disinfection and sterilization, formaldehyde removal, odor removal, nicotine purification, etc. It is an internationally recognized green and efficient disinfectant, commonly used in hospital sewage disinfection and air disinfection and widely used in Europe, America, Japan, and other developed countries. However, chlorine dioxide and hypochlorite disinfection solution is very volatile and will lose its effect during a long time of light in the process of storage, so it should not be stored for a long time and needs to be dispensed as it is used.

3.2 Nonchlorine disinfectants

Peroxyacetic acid and hydrogen peroxide are often used in air disinfection by spraying or fumigation because of their strong oxidizing properties. By making the active ingredients in the disinfectant interact with microorganisms' outer layer proteins, glycoproteins, membrane lipids, and other macromolecules, the synthesis of RNA, DNA, and proteins is inhibited, thus killing the microorganisms in the air. Currently, dry mist hydrogen peroxide disinfection systems are mostly used, and the Chinese Technical Specification for Disinfection in Medical Institutions also proposes that indoor air disinfection can be carried out by spraying hydrogen peroxide. Hydrogen peroxide has many advantages as a highly effective disinfectant, such as a concentration below 3% can be used for disinfection, 6% or more can be used for sterilization and the sterilization effect is fast, sterilization ability is strong, the sterilization spectrum is wide; at the same time, it has the advantages that other low-temperature disinfectants do not have, such as less irritation, low corrosion, easy to undergo gasification into oxygen and water, no pollution to the environment, no residual toxic substances, etc., and aerosol disinfection, both. It can ensure uniform disinfection area and wide coverage, and avoid the problems of limited irradiation distance and dead angle of physical UV method, and solve the problems of consumables' replacement, microbial enrichment, and secondary pollution of electrostatic adsorption and filtration method.

In recent years, chemical disinfectants for terminal disinfection in medical institutions and epidemic source sites are commonly used for disinfection by hydrogen peroxide fogging. However, it is necessary to consider that the chemical components in the spray may cause allergy, asthma, nausea, headache, memory loss, and other symptoms in some people in the air. And chemical disinfectants are strong disinfectants, which are only suitable for indoor air disinfection in unoccupied situations, such as laboratory or end-of-life air disinfection at the source of the epidemic, but for disinfection at any time inwards, homes, offices, etc., it is necessary to coordinate the time of human and machine disinfection, and to use human-machine simultaneous operation of disinfection in the same field. Moreover, chemical disinfectants are generally irritating and corrosive, with a certain lag and decay in prevention and control effects, so they are mostly suitable for indoor air disinfection in unoccupied conditions.

3.3 Chemical surfactants

Surfactants are also one of the commonly used disinfectants, which can be used not only for disinfection and sterilization of the surface of articles but also for topical clinical skin application and prevention of postoperative infections, and are widely used in daily life, medical hygiene, wound treatment, and other fields. These agents are low in toxicity, noncorrosive, stable for long-term storage, have a wide range of disinfection, are effective and fast, and have a strong killing effect on pathogenic bacteria in general. In people's daily life, chemical disinfection is mainly reflected in bare skin such as hands, furniture, and electronic equipment. For disinfection of human hands, it was found that soap washing has the best total bacteria removal effect compared to alcohol. Repeated hand washing and the use of disinfectants can cause significant skin dryness and contact dermatitis.

4. Other disinfection methods

Some studies have compounded with low toxicity, residue-free permethrin, compound quaternary ammonium salts, guanidine, and other safe raw materials to develop a new compounded fogging disinfectant that can effectively disinfect the environmental air of containers used for transportation.

In addition, Chinese herbal air disinfection is also commonly used in medical, home, and other indoor places. Chinese medicine fumigation for air disinfection method has a long history, "the elbow after the preparation of the urgent formula" will be the first to propose the air disinfection method of Chinese medicine fumigation, such as "Taiyi Liujin formula … in the court of burning, warm patients also burn fumigation." Chinese medicine disinfection has strong broad-spectrum antibacterial and antiviral effects and can achieve effective and safe disinfection at the same time, but is also nontoxic to humans and the environment, has abundant resources, is stable, low priced, and is simple to use. Mo Qian [5] et al. found that mugwort, atractylodes, patchouli, peppermint, honeysuckle, forsythia, and other heat-clearing and damp-relief drugs were mostly used for air disinfection in Chinese medicine. This method is inexpensive, simple to operate, overcomes the disadvantages of chemical disinfectants, safe and effective, nonirritating to humans, noncorrosive to objects, and is more suitable for use in environments with high personnel density and easy contamination. Application in the medical environment: In clinical studies on disinfection of hospital wards, it was found that mugwort leaves, when used for air disinfection, could significantly reduce the number of harmful microorganisms in the environment, with comparable or even better effects than ultraviolet light and chemical disinfectants, but the disinfection time of herbal medicine is longer and there may be problems of secondary contamination. The newly developed *Atractylodes macrocephala* oil microcapsules also have a certain killing effect on natural indoor air bacteria by heating and fumigation. During the COVID-19 airborne outbreak, indoor air disinfection can make essential indoor spaces, such as clinical and daily homes, safer. In daily household life, the use of herbal disinfection both ensures its ideal disinfection effect and enhances indoor comfort, which is becoming increasingly popular for household disinfection.

5. Summary

Traditional single physical and chemical disinfection is prone to secondary air pollution and certain toxic side effects, each with its advantages and disadvantages. Therefore, it is necessary to develop a reasonable disinfection process and strategy that combines physical, chemical, and biological methods to synergize disinfection. Overdisinfection can be avoided while ensuring the disinfection effect [10]. This is because overdisinfection can affect the environment and the balance of microorganisms in the plant and animal, water and soil environments, and even bring about the spread of antimicrobial resistance.

In future research, the study of biomedical mechanisms of the action of physical means and bacterial viruses should be strengthened to avoid environmental pollution by applying cost-effective sterilization and disinfection techniques. Reducing the cost of sterilization and sterilization equipment, achieving green, environmentally friendly, fast, and portable characteristics, ensuring no damage to the human body, and realizing the completion of sterilization and disinfection of indoor air and objects under human conditions still need further research and improvement.

Author details

Shouguo Wang[1*], Bin Yan[2] and Li Song[1]

1 Qilu University Technology, China

2 Shandong University of Traditional Chinese Medicine, China

*Address all correspondence to: wangshouguo@aoe.ac.cn

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