The Applications of Ozone gas in Hospitals for Disinfecting and Sterilizing the Air, Surfaces and Equipment Contaminated with the COVID-19 Virus: A Comprehensive Review

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Abstract

Background and aims: The COVID-19 has created important challenges for hospitals in terms of safe and safe environment for patients and health care staff. Traditional disinfectants may not be sufficient to combat the very contagious nature of the virus. This study was aimed at examining the existing literature on the use of ozone gas in hospitals for disinfecting and sterilizing of air, surfaces and equipment contaminated with COVID-19.

Methodology: To do this, various databases, including PubMed, Scopus and Google Scholar, were reviewed for relevant articles published between January 2010 and July 2023. Following the screening of articles based on their titles and summaries, they were selected that specifically cited ozone gas applications for disinfection and sterilization purposes in hospitals.

Results: The review demonstrated that ozone gas can disable the virus on surfaces and air. In addition, ozone gas is effective in removing the remaining virus in infected medical equipment. The study also revealed that the use of ozone gas for disinfection in hospital environments is possible.

Conclusions: The use of ozone gas is an effective way to disinfect and sterilize air, surfaces and equipment infected with COVID-19 in hospitals. However, more extensive studies are essential for optimizing concentration and time exposure to this gas as well as the implementation of immune protocols.

Keywords: Ozone gas, Disinfection, Sterilization, COVID-19, Hospitals, Air, Surfaces, Equipment

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Introduction

Coveid-19 is a respiratory disease caused by a new coronavirus called Sars-COV-2. This was first identified in December 2019 in Wuhan, China, and has spread worldwide since then, and as a result, the disease is epidemic [1]. Coveid-19 is primarily transmitted through respiratory droplets where a person infected cough, sneezing, negotiation or breathe. It can also be spread by touching an infected surface or object and then touching the face, although this is less common [2]. The virus enters the body through the nose, mouth, or eye and attaches to the cells of the respiratory system. Symptoms of Coveid-19 can range from mild to severe and usually appear within 14 to 2 days of exposure. Common symptoms include fever, cough, shortness of breath, fatigue, muscles or body pain, headaches, sore throat, loss of taste or odor, nose or runny, nausea or vomiting and diarrhea [3, 4].

Understanding the characteristics of the virus and its durability at various levels and objects is important for the implementation of effective preventive measures. It is important to note that the COVID-19 virus can be suspended in the form of respiratory droplets in the air for a short period of time [5]. These droplets are relatively heavy and tend to be quickly deployed on the surfaces and convert the individual to the individual to the most common state of infection. Studies have shown that the COVID-19 virus can survive at different levels and objects for different periods [6]. The survival of the virus at the levels can range from several hours to several days. However, it is important to note that the viral load level decreases over time and reduces the risk of transmission. The virus can survive for up to 2-3 days on plastic and stainless steel surfaces [7]. The virus can also survive for up to 24 hours on cardboard levels. Additionally, the virus can survive for about 4 hours on copper levels. Various factors can affect the durability of the virus on surfaces and objects such as environmental conditions, surface type, and disinfectant. The virus tends to survive in areas with lower temperatures and humidity, compared to higher temperatures and humidity levels [8]. Porous surfaces such as cardboard may cause the virus to dry more rapidly and lead to the duration of survival compared to non -porous surfaces such as plastic or stainless steel. Proper disinfection can significantly reduce the time of virus survival on the surfaces. Detergents, alcohol -based disinfectants and oxidants such as chlorine and ozone compounds can effectively inactivate the virus [9, 10].

Ozone (O_3) is a highly reactive and unstable molecule consisting of three oxygen atoms. Due to the strong oxidizing properties, this substance has been widely used for disinfection purposes in various industries [11, 12]. It is very effective against a wide range of microorganisms, including bacteria, viruses, fungi and single cells. It can effectively eliminate harmful microorganisms in the air, water and surfaces [13, 14]. Ozone gas works quickly and efficiently in disinfectant processes. This can cause microorganisms within seconds to minutes from exposure. Unlike traditional disinfectants that leave chemical residues, ozone gas is decomposed into oxygen after use. Ozone gas is a natural substance and does not release any harmful chemicals in the environment. This is a stable disinfectant because it can be manufactured using electricity and ambient air on the site [15].

Ozone gas is widely used in hospitals due to its disinfectant properties. It can effectively eliminate bacteria, viruses and other pathogens. It can be used in ventilation systems to pass the air through the ozone generator. This helps to create a safer environment for patients, employees and visitors [16]. Ozone gas can be used to sterilize different levels in hospitals, including bed sheets, curtains, furniture, medical equipment and operating rooms. It is effective in killing bacteria, fungi and viruses on surfaces and reduces the risk of health care -related infections. In addition, rigid and non -porous medical equipment, such as surgical tools, endoscopes and respiratory equipment can be effectively sterilized using ozone gas. Ozone helps eliminate microbial contamination and minimize the risk of mutual infection during medical procedures [17]. It can help neutralize odor, eliminate bacteria and viruses, and create a safe and clean environment for patients and medical staff. In addition, ozone gas can be used to disinfect medical waste such as bandage, syringe and other contaminated substances. This gas is effective in removing unpleasant odors caused by chemicals, body fluids and other sources in hospitals [18]. It is important to note that ozone gas should be used with caution and in controlled values, as high concentrations can be harmful to humans and may cause respiratory problems. Proper training, monitoring and maintenance of ozone systems in hospitals are essential to ensure safe and effective disinfection and sterilization processes [19].

Extensive studies have been conducted on the use of ozone gas as a disinfectant in hospitals. In a study, Zoutman et al. investigated the effectiveness of a novel ozone-based system for the rapid high-level disinfection of health care spaces and surfaces. The results of their study showed that ozone hydrogen peroxide vapor system provides a very high level of disinfectant steel and gas levels against bacterial pathogens associated with health care [20]. Similarly, Alshehri et al. evaluated the effectiveness of gas ozone as disinfectant for hospital pathogens in a health care emergency. The results of this study indicated that gas can be an effective, safe and inexpensive disinfectant in hospitals and medical centers [21]. In another study, Irie et al. provided sufficient information about the effectiveness of ozone gas in virus inactivation of surfaces and objects in healthcare environments. The results of this study demonstrated that ozone gas is promising for viral disinfection of surfaces [22]. The continuation of the COVID-19 virus in non-living environments and the ability to quickly transfer it to people in the hospital shows the need to use a powerful disinfectant [23]. The aim of this study was to evaluate the possible applications of ozone gas in hospitals for disinfectant and sterilize air, surfaces and equipment contaminated with viruses, especially the COVID-19 virus. By reviewing research and studies on ozone gas, its efficiency, safety and feasibility were examined as a disinfectant in health care environments.

Background

In hospitals, the presence of viruses and other pathogens causes a great risk for patients, employees and visitors. Therefore, maintaining a clean and sterile environment is very important to prevent the spread of infection [24]. Due to the strong oxidizing properties and the ability to eliminate a wide range of pathogens, ozone gas is increasingly known as an effective disinfectant and disinfectant. Ozone (O_3) is a highly reactive gas consisting of three oxygen atoms [25]. It can be produced by converting oxygen (O_2) using electric discharge or ultraviolet light. Ozone gas has been used for years in water and air purification because of its ability to quickly and efficiently eliminate bacteria, viruses, fungi and other microorganisms [26]. The use of ozone in medical centers has also shown promising results in reducing the transmission of hospital infections (HAIs). In hospitals, ozone gas can be used in various ways to disinfect and sterilize air, surfaces and equipment. One of the most common methods is ozone or ozone -based air purification [27]. These devices are released ozone in the air, where it reacts with organic matter such as bacteria or viruses and breaks them into the molecular level. This process effectively eliminates any potential source of infection in the air and reduces the risk of air transmission. In addition, ozone can be used to disinfect surfaces and equipment [28]. The gas can penetrate porous materials and reach areas where traditional cleaning methods may not be effective. It can eliminate bacteria, viruses and other pathogens at surfaces including tables, beds and medical equipment [29]. It has also been shown that ozone gas is effective in sterilizing reusable equipment such as surgical tools by killing the remaining microorganisms after the initial cleaning process. In addition, ozone gas can be used to disinfect room [30]. Hospital rooms, especially those occupied by patients with communicable diseases, need complete cleaning and disinfection to prevent mutual infection. Ozone generators can be placed in an empty room and can be blocked before ozone therapy activation [28]. The gas circulates throughout the room for a certain period of time and effectively kills any remaining pathogens on the surfaces. It is important to note that ozone gas should only be used in empty spaces or in periods where patients, employees and visitors are not present because of its potential respiratory stimulant effects [31]. To ensure safety, the ozone surface must be carefully controlled and controlled. In addition, proper ventilation after ozone treatment is essential to eliminate any residual gas. In general, ozone gas has been proven to be a valuable tool for disinfectant and sterilization of air, levels and equipment in hospitals [32]. Its strong oxidizing properties and its ability to eliminate a wide range of pathogens make it an effective option to reduce infection transmission. However, proper precautions and instructions must be taken to ensure safe and effective use of ozone gas in health care environments [28].

Methodology

The aim of this study was to investigate the potential applications of ozone gas for disinfection and sterilization of air, surfaces and equipment infected with the COVID-19 virus in hospitals. To conduct this review study, various databases including PubMed, Scopus, and Google Scholar for relevant articles published between January 2010 and July 2023 was searched. The keywords such as "ozone gas," " COVID-19," "disinfection," "sterilization," "air," "surfaces," and "equipment" to identify relevant studies were used. After screening the articles based on their titles and abstracts, studies that specifically dealt with ozone gas applications in hospitals for disinfection and sterilization purposes were selected. Finally, the relevant studies were included in this review.

COVID-19

The COVID-19 is a highly contagious respiratory disease caused by the novel coronavirus SARS-CoV-2. It was first identified in Wuhan, China in December 2019 and has since spread globally, resulting in a pandemic [33]. Symptoms of COVID-19 can range from mild to severe and may include fever, cough, fatigue, shortness of breath, loss of taste or smell, and body aches. This can lead to severe respiratory distress and death, especially in the elderly and those with underlying medical conditions [34]. Covid-19 is primarily transmitted through respiratory droplets when an infected person coughs, sneezes, talks, or breathes heavily, but it can also spread by touching contaminated surfaces and then touching the face. In order to prevent the spread of Covid-19, people are advised to observe hygiene measures such as frequent hand washing, wearing a mask, physical distance from others and avoiding large gatherings. Vaccines have been developed to fight Covid-19 and are being distributed around the world to help control the spread of the virus [35].

Ozone gas

Ozone gas is a molecule that consists of three oxygen atoms (O_3). It is pale blue gas with pungent smell. Ozone occurs naturally in the Earth's upper atmosphere, where it forms a protective layer called the ozone layer [36, 37]. This layer filters most of the sun's harmful ultraviolet (UV) rays and prevents them from reaching the earth's surface. Ozone gas is also produced artificially through various processes such as electric discharge or ultraviolet radiation to be used in various applications [38, 39]. It has strong oxidizing properties that make it a useful disinfectant and deodorizer. Ozone gas can kill bacteria, viruses and other microorganisms, making it an effective disinfectant for air and water purification [28]. It is also used in industrial processes such as bleaching and chemical synthesis. However, ozone gas can also be harmful to human health and the environment [40, 41]. Breathing in high levels of ozone can cause breathing problems, chest pain, and throat irritation. Ground-level ozone pollution is a major component of smog and can contribute to air quality problems. Therefore, monitoring and regulating ozone levels is very important to protect human health and the environment [19].

The inactivation of viruses by ozone

In recent years, the world has seen outbreaks of various viral diseases, from the dreaded Ebola virus to the ongoing COVID-19 pandemic. As a result, scientists and researchers have been tirelessly researching various methods to combat these invisible enemies [42]. One of these solutions that have attracted a lot of attention is the use of ozone gas to inactivate viruses. Using ozone gas to inactivate viruses involves exposing the target area or object to a high concentration of ozone gas [3, 4]. When ozone molecules come into contact with the outer shell of the virus, they penetrate through the protein coat, oxidize and eventually destroy the viral RNA or DNA. This process, known as oxidation, renders the virus unable to reproduce and infect host cells. Several studies have shown the effectiveness of ozone gas in inactivating various viruses [43]. For example, research conducted by the National Institute for Occupational Safety and Health (NIOSH) found that ozone effectively inactivates adenovirus, norovirus, and rotavirus particles [44, 45]. Similarly, studies on the inactivation of the influenza virus have shown promising results, as ozone gas was able to reduce the infectivity of the virus by more than 99%. One of the significant advantages of ozone gas for virus inactivation is its ability to reach hidden or inaccessible areas. Unlike liquid disinfectants, which may not be able to penetrate certain surfaces, ozone gas can easily diffuse through porous materials, fabrics, and cracks [46]. This makes it an ideal solution for disinfecting objects or areas that may be difficult to clean using conventional methods. In addition, ozone gas offers a fast turnaround time for disinfection. While traditional disinfection methods may require prolonged exposure or drying time, ozone gas works quickly and neutralizes viruses within minutes [47]. This makes it particularly useful in environments where time is of the essence, such as hospitals, schools and public transport. Another significant advantage of ozone gas is its compatibility with the environment. Unlike many chemical disinfectants that are harmful to the environment, ozone gas breaks down naturally into oxygen after use and leaves no harmful effects [30]. This makes it a safe, stable and cost-effective option for virus inactivation. It is important to note that while ozone gas is very effective at inactivating viruses. Its safe use requires proper precautions and expertise. Ozone gas, if inhaled in high concentrations, can be harmful to humans and lead to respiratory problems [19]. Therefore, it is important to ensure adequate ventilation during the application process and follow recommended safety guidelines. The use of ozone gas to inactivate viruses offers a promising solution in the fight against viral diseases. Its ability to quickly and effectively neutralize a wide range of viruses, while being environmentally friendly, makes it a valuable tool in a variety of settings. However, caution and adherence to safety protocols are necessary to maximize benefits while minimizing potential risks [48].

Inactivation of viruses in the enclosed spaces of hospitals

In recent years, the world has faced the rapid spread of infectious diseases, which indicates the need for effective measures to fight and prevent the transmission of viruses. One of these methods is the use of ozone to deactivate viruses in the air, especially in hospital environments [17]. As healthcare centers, hospitals are naturally prone to the presence of viruses and harmful bacteria. These pathogens can be easily transmitted through the air and pose a significant risk to patients and healthcare workers [44]. Traditional disinfection methods, such as surface cleaning and hand hygiene, may not completely reduce this airborne transmission. Ozone, a highly reactive form of oxygen, has long been known for its powerful disinfectant properties [28]. It works by removing the outer protein coat of the virus, thereby inactivating it. Ozone has the ability to penetrate even hard-to-reach areas, making it an effective way to reduce the spread of viruses in hospital environments. One of the key benefits of ozone is its ability to provide continuous disinfection [49]. Unlike traditional disinfectants that require repeated applications, ozone can be generated and released into the air to continuously disinfect the surrounding environment. This is especially important in hospitals where the risk of virus transmission is constant. In addition, ozone-based systems do not rely on human intervention, reducing the possibility of human error and ensuring continuous disinfection [50]. Once the ozone generator is set up, it can be programmed to release ozone at regular intervals, ensuring a constant and controlled level of disinfection in the air. In addition, ozone has a shorter contact time compared to other disinfectants. Traditional disinfectants usually require a certain amount of time to become effective, potentially leading to a delay in disinfection [51]. Ozone, on the other hand, acts almost immediately upon contact with viruses, ensuring rapid inactivation and reducing the risk of transmission. Additionally, the use of ozone in the air leaves no residue or by-product that could potentially harm patients or staff. Traditional disinfectants, such as bleach or hydrogen peroxide, may leave toxic residues or fumes that can be harmful to human health [22]. Ozone, which is a natural gas, decomposes into oxygen and does not leave any harmful effects. However, it is important to note that while ozone has strong antiseptic properties. Its implementation needs careful consideration [52]. Ozone concentrations must be carefully monitored to ensure that they do not exceed recommended levels, as high concentrations can be harmful to humans. A balance between effective disinfection and passenger safety is essential. Consequently, the use of ozone has great potential in inactivating viruses in hospital air [22]. Ozone-based systems can significantly reduce the risk of virus transmission in healthcare settings by providing continuous disinfection, the ability to reach inaccessible areas, and rapid action against viruses. However, ensuring proper monitoring and regulation of ozone concentration is critical to achieving effective disinfection while maintaining the safety of patients and staff [53].

Inactivation of viruses in the patient and operating rooms surfaces

Traditional cleaning methods may not always be sufficient to remove viruses from patient and operating room surfaces. However, a promising solution is the use of ozone. Ozone easily reacts with organic substances, including viruses, and as a result, cell membranes and their genetic material are destroyed. One of the significant benefits of ozone is its ability to reach and disinfect hard-to-reach areas [54]. In patient and operating rooms, various surfaces such as tables, surgical equipment, and ventilation systems can harbor the virus. Ozone treatment, which can be applied as a gas or liquid, can effectively penetrate these surfaces and ensure complete disinfection. This is especially important in operating rooms where invasive procedures carry a higher risk of virus transmission [55]. Moreover, ozone has a wide range of antimicrobial activity. It has been shown to effectively inactivate a wide variety of viruses, including enveloped and non-enveloped viruses. Enveloped viruses such as influenza virus and coronaviruses are sensitive to ozone due to the lipid layer surrounding their genetic material. By attacking this lipid layer, ozone disrupts the integrity of the virus and deactivates it. Besides, ozone is a fast-acting disinfectant [9]. Studies have shown that even short-term exposure to ozone can lead to significant reductions in viral loads. This is especially important in healthcare environments where rapid patient handling and operating rooms are essential. With ozone, healthcare providers can achieve a high level of disinfection in a short period of time, minimizing the risk of virus transmission between patients. Another important benefit of ozone is its compatibility with the environment [56]. Unlike traditional disinfectants such as chlorine, ozone does not leave harmful residues or produce toxic byproducts. Ozone quickly reverts to oxygen after use, making it a safe and sustainable disinfection option. Its use in patient and operating rooms can contribute to a healthier and safer environment for healthcare providers and patients. While the use of ozone shows promise in inactivating viruses on patient and operating room surfaces, it is important to note that proper implementation and adherence to safety guidelines are critical [51]. If not used correctly, ozone can be harmful to human health. Therefore, it is essential that healthcare facilities use trained professionals to perform ozone therapy and ensure proper ventilation during the disinfection process. The use of ozone to inactivate viruses on patient and operating room surfaces shows significant potential in reducing the risk of virus transmission in healthcare settings [57]. The ability to access hard-to-reach areas, a wide range of antimicrobial activity, fast-acting nature and compatibility with the environment has made it a valuable tool in the fight against infectious diseases. As research and technology continue to advance, ozone may become an integral part of routine disinfection protocols, helping to create safer healthcare environments for all [17].

Inactivation of viruses in medical equipment in hospitals

In hospitals where patients with various diseases are treated, the risk of transmission of the virus is significantly higher. To combat this issue, the use of ozone has emerged as a promising solution to effectively inactivate viruses in medical equipment. Contaminated equipment can serve as a breeding ground for viruses and other infectious agents, potentially leading to cross-contamination and the spread of disease [27]. Traditional sterilization methods, such as autoclaving or chemical disinfection, may not always be effective against some viruses, making ozone an attractive alternative. One of the key advantages of using ozone to inactivate viruses is its ability to reach all surfaces, including hard-to-reach areas and complex medical instruments [17]. Ozone can easily penetrate into gaps and tight spaces and ensure complete disinfection. In addition, ozone leaves no harmful residues or byproducts, making it environmentally friendly for patients and healthcare workers. Several studies have shown the effect of ozone in inactivating different viruses. For example, a study published in the Journal of Hospital Infection found that ozone effectively inactivated influenza virus, respiratory syncytial virus, and adenovirus. Another study published in the Journal of Medical Virology found that ozone gas is effective against human immunodeficiency virus (HIV) and hepatitis B virus (HBV) [58]. Additionally, ozone has been shown to be effective against emerging viruses such as the novel coronavirus (SARS-CoV-2) that causes COVID-19. A study reported that ozone gas rapidly inactivates SARS-CoV-2 on surfaces, making it a promising method for preventing the spread of the virus in healthcare settings. It is relatively simple to implement ozone-based virus inactivation systems in hospitals. Ozone generators can be installed in designated areas where medical equipment is processed and stored [25]. These generators convert oxygen into ozone and then circulate in closed spaces, guaranteeing complete disinfection. In addition, ozone concentration levels can be measured and controlled to ensure optimal disinfection without posing a risk to human health. While ozone offers countless benefits for virus inactivation, there are some considerations to keep in mind. Ozone gas is toxic in high concentrations, so proper ventilation is essential to prevent overexposure [59]. Furthermore, ozone may corrode certain materials, so compatibility testing is necessary to ensure the integrity of medical equipment. The use of ozone to inactivate viruses in medical equipment in hospitals is promising. Its ability to penetrate hard-to-reach areas, its eco-friendly nature, and its demonstrated effectiveness against a wide range of viruses make it an attractive option. As the world continues to face viral outbreaks, the use of ozone-based disinfection systems can help hospitals maintain a sterile environment and prevent the spread of infectious diseases [60].

The COVID-19 virus inactivation in hospitals

The Covid-19 pandemic has raised awareness of the need for effective disinfection practices in hospitals and healthcare facilities. As health care workers work to protect their environment, various methods have been employed to combat the spread of the virus. One of these methods that have received attention is the use of ozone in virus inactivation. When it comes to Covid-19, ozone has shown promise in inactivating the virus and reducing its spread in hospitals [3]. Studies have shown that ozone effectively removes the virus from surfaces such as floors, walls, and equipment, as well as from the air. This makes it a valuable tool in preventing cross-contamination and reducing the risk of infection among healthcare workers and patients. One of the primary benefits of ozone is its ability to reach all corners of a room or facility. Unlike traditional cleaning methods, which may miss certain areas or rely on manual labor, ozone gas disperses evenly and penetrates hard-to-reach spaces, ensuring complete disinfection [61]. This is especially important in hospital environments, where surfaces and objects can become reservoirs of the virus and pose a constant threat to healthcare workers and patients. In addition, ozone provides a fast and efficient disinfection process. Within minutes, ozone can neutralize the Covid-19 virus and provide rapid turnaround times for hospital rooms and equipment. This is essential in maintaining a safe environment for patients, minimizing the risk of transmission and optimizing the use of resources [28]. Another notable benefit of ozone is its environmentally friendly nature. Unlike other chemical disinfectants, ozone does not leave behind harmful residues or byproducts. After the disinfection process is completed, ozone returns to its original form, oxygen, and no traces of chemicals that may be harmful to humans or the environment remain. This makes ozone an attractive solution for hospitals seeking to maintain a sustainable and environmentally friendly approach to disinfection. It is important to note that while ozone can effectively inactivate the COVID-19 virus, proper training and protocols must be followed to ensure its safe and effective use [62]. Ozone can be harmful to humans if not used properly, so it is very important that hospitals and healthcare facilities receive proper guidance and training on its use. Further, ozone use should be part of a comprehensive approach to infection prevention, including regular cleaning and disinfection practices, use of appropriate personal protective equipment (PPE), and adherence to standard hygiene protocols. In summary, ozone shows great potential in combating COVID-19 in hospital settings. Its ability to effectively inactivate the virus, reach all areas of a facility, and provide rapid disinfection makes it a valuable tool in preventing the spread of infection. As hospitals continue to face the challenges of this pandemic, the use of ozone as part of their disinfection strategies can play an important role in maintaining a safe and healthy environment for healthcare workers and patients alike [11].

Interpretation

This review revealed several key findings regarding ozone gas applications in hospitals for disinfection and sterilization. Ozone gas can effectively disinfect hospital air by oxidizing and inactivating airborne pathogens, including the Covid-19 virus. Ozone generators equipped with proper ventilation systems can be strategically placed to ensure complete coverage and maximum effectiveness. The gas also can be applied to surfaces inside hospitals to disinfect high-touch areas such as doorknobs, railings, and room tables. Its ability to penetrate small gaps and reach inaccessible areas makes it an attractive option for complete surface sterilization. Moreover, the review demonstrated that ozone gas can be used to sterilize various medical equipment including ventilators, masks and surgical instruments. Its rapid action and non-toxic nature make it a suitable alternative to traditional methods such as thermal and chemical sterilization. While ozone gas has demonstrated effective disinfection properties, certain precautions must be taken. Based the review, ozone concentration must be carefully regulated to avoid adverse health effects on health care workers and patients. Proper ventilation and monitoring systems must be in place to maintain safe levels of ozone gas [63]. Several studies have demonstrated that ozone gas is very effective in inactivating the Covid-19 virus. In one study, ozone used at a concentration of 0.4-2 mg 03/L, achieved a 4.2-6 log inactivation of HAV and 3.9-4.9 log inactivation of MS2. In another study, ozone at a concentration of 0.6-1.76 mg 03/L achieved a 2.96-7.00 log inactivation of MS2 and 1.63 to greater than 3.6 log inactivation of poliovirus type 3 [64]. In order to define the interactions of ozone with viruses, candidate viruses which represent a wide range of diversity among the virus families must be selected [64]. Tanaka, Sakurai [65] inactivated influenza viruses, herpes virus, adenovirus, and vesicular stomatitis virus under different ozone concentrations ranging from 800 to 1500 ppm and with this mechanism demonstrated that ozone is effective in inactivating a wide range of viruses. Tanaka, Sakurai [65] also conducted a study on ozone decontamination of viruses and concluded that; (1) when the ozone concentration was 0 ppm, the influenza virus that has dried on the carriers maintained a high infectivity even after 10 hours; (2) when the ozone concentration was between 10 and 20 ppm, the infectivity of the influenza virus decreased logarithmically over time; (3) when the ozone gas concentration was 20 ppm, 99.999% of the influenza virus was inactivated after 2.5 hours of fumigation, and when the ozone concentration was 10 ppm, not less than 99.99% of virus was inactivated after 3.5 hours of fumigation. There is limited data on the inactivation of viruses transmitted by the air [66]. Ozone may first inactivate the protein capsid, and then the naked nucleic acid may be secondarily inactivated. In virus inactivation, ozone concentration, contact treatment, and the type of viral capsid protein are suggested to play important roles [66]. Virus required ozone doses of 0.34–1.98 and 0.80– 4.19 min-mg/m^3 for 90% and 99% inactivation, respectively [66]. Compared to non-enveloped viruses, the enveloped types are more sensitive to chemical disinfectants because they require an intact lipid envelope to infect host cells, and this envelope can be damaged by chemical and physical agents [61]. High relative humidity is associated with superior antimicrobial effects of ozone [20]. This humidification could reduce the treatment time and lead to a better overall efficacy [67]. However, the optimal requirement for high humidity suggests the possible involvement of additional radicals, such as hydroxyl ion and peroxides, which could be generated under those conditions [32]. Tseng and Li [66] observed that microorganism susceptibility to ozone was significantly higher when relative humidity (RH) increased. Regarding the RH effects, the susceptibility for viruses was higher at 85% RH than that at 55% RH. This might be related to the generation of more radicals from ozone that reacted with more water vapor at higher RH [66]. An exposure time of at least 40 minutes at 85% RH was most effective for the inactivation of the other viruses using ozone [67]. Hudson, Sharma [68] also examined the role of high humidity in increasing the virus inactivation process, and included this feature in the field tests. Studies have shown that the presence of ozone in high RH conditions leads to the formation of more radicals than in dry air. More free radicals can further inactivate the virus. The recommended exposure limit set by NIOSH for ozone is 0.1 ppm and this exposure level cannot be exceeded at any time [56]. However, because this gas is harmful to humans at concentrations higher than this value, patients and staff should not be present during air disinfection if the concentration is higher than 0.1 ppm [67]. Moreover, testing must be accomplished for possible ozone leakage when doors are closed in order to evaluate the feasibility of treatment. For better protect, ozone destructors can also be used and operated in the hallway near the closed door of the hospital rooms and inside them when the treatment is performed [21].

Ozone works by breaking down the outer protein coat of the virus, making it unable to infect humans. Ozone gas can be used for air disinfection in hospital environments. By reacting and destroying their proteins and lipids, it helps to destroy airborne pathogens, including the Covid-19 virus. This helps reduce airborne transmission of the virus. This gas is effective in sterilizing various surfaces infected with the Covid-19 virus [36]. Studies have shown that ozone gas can inactivate the virus on various surfaces including metal, plastic, glass and fabric. This makes it very useful in disinfecting hospital equipment, furniture and commonly touched surfaces. Ozone gas has the advantage of reaching areas that are difficult to disinfect using traditional cleaning methods [69]. It can penetrate porous materials such as fabric and upholstery and provide complete disinfection throughout the hospital environment. Unlike many chemical disinfectants, ozone gas does not leave traces on surfaces after use. This minimizes the risk of chemical exposure to healthcare workers and patients. Ozone gas should be used with caution and under controlled conditions. It is important to follow recommended exposure limits, as high levels of ozone can be harmful to humans. Appropriate supervision and safety precautions must be observed to ensure the well-being of health care personnel and patients [70]. Overall, this review revealed that ozone gas shows great potential as a disinfectant and disinfectant in hospitals to combat the Covid-19 virus. However, further research and standardized protocols are needed to establish optimal ozone concentrations, exposure durations, and application methods for different hospital environments.

Conclusions

A study on the use of ozone gas in hospitals to disinfect and sterilize air, surfaces and equipment contaminated with the Covid-19 virus provided valuable insights. Ozone gas has shown promising results in disinfecting and sterilizing air, surfaces and equipment infected with the Covid-19 virus in hospitals. This review showed its ability to inactivate the virus and reduce its transmission in medical centers. Ozone gas can reach areas that are difficult to clean with conventional methods, such as corners, corners and ventilation systems. This makes it a potentially valuable tool for comprehensive disinfection in hospitals. The use of ozone gas in hospital environments requires careful attention to safety guidelines and regulations. Ozone gas can be harmful if not used correctly, and adequate ventilation and monitoring systems must be in place to ensure the safety of healthcare workers and patients. In addition, the concentration and contact time of ozone gas are important factors that must be considered for effective disinfection. Higher ozone concentrations and longer exposure times have been shown to increase the virucidal effect, but precautions must be taken to avoid possible side effects. Although the use of ozone gas for disinfection purposes has shown promise, more research is needed to develop optimal protocols and guidelines for its use in hospitals. This includes determining safe and effective concentration levels, exposure times, and compatibility with different surfaces and equipment. In conclusion, this study highlights the potential of ozone gas as a valuable tool for disinfection and sterilization in hospitals infected with the Covid-19 virus. However, careful review of safety guidelines, further research, and standardized protocols are necessary to ensure its successful implementation in healthcare settings.

Ethics statement

Not applicable.

Author contribution statement

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