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Review

Disinfectants against SARS-CoV-2: A Review

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Abstract: The pandemic due to Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) has emerged as a serious global public health issue. Besides the high transmission rate from individual to individual, indirect transmission from inanimate objects or surfaces poses a more significant threat. Since the start of the outbreak, the importance of respiratory protection, social distancing, and chemical disinfection to prevent the spread of the virus has been the prime focus for infection control. Health regulatory organizations have produced guidelines for the formulation and application of chemical disinfectants to manufacturing industries and the public. On the other hand, extensive literature on the virucidal efficacy testing of microbicides for SARS-CoV-2 has been published over the past year and a half. This review summarizes the studies on the most common chemical disinfectants and their virucidal efficacy against SARS-CoV-2, including the type and concentration of the chemical disinfectant, the formulation, the presence of excipients, the exposure time, and other critical factors that determine the effectiveness of chemical disinfectants. In this review, we also critically appraise these disinfectants and conduct a discussion on the role they can play in the COVID-19 pandemic.

Keywords: SARS-CoV-2; disinfectant; virucidal activity; alcohol; quaternary ammonium salt; chlorine-releasing agents; chlorine dioxide; hydrogen peroxide and peracetic acid; iodophor; ozone

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1. Introduction

Since the first outbreak at the end of 2019, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is still raging around the world, bringing about detrimental effects to the world economy and society [1–3]. As of May 2022, there have been over 515 million confirmed cases of COVID-19, including more than 6 million deaths, reported by the World Health Organization (WHO) [4]. Current studies suggest that the SARS-CoV-2 virus can spread from an infected person's mouth or nose in small liquid particles when they breathe, sneeze, cough, or speak [5]. It may also be transmitted via contact by touching contaminated surfaces, followed by touching the mouth, nose, or eyes. Experimental studies have shown that SARS-CoV-2 can survive on various plastic, latex, glass, and metal surfaces for hours to days [6]. Additionally, epidemiological evidence from the field suggests that the virus can survive on the outer packaging of cold-chain foods kept in a low-temperature environment and has been proven to maintain infectivity [7,8]. Therefore, the fomite transmission of SARS-CoV-2 is certainly plausible [9].

A highly effective treatment for this emerging infectious disease is lacking to date, although several drugs and vaccines have been found to improve clinical outcomes in large trials, and the rapid development and production of vaccines has permitted large-scale vaccination in many countries [10–12]. However, vaccine development still faces challenges, even with novel platforms [13]. More evidence is required before we know exactly how effective these drugs and vaccines are, especially when new virus variants constantly emerge [14,15]. These challenges become even greater due to the virus's high transmissibility rate and long incubation period, as was evident with the Omicron variant [3]. In this context, preventive measures such as rapid detection, the isolation of cases, and the early quarantining of close contacts of positive cases, as well as mask use, physical distancing,

10. Ozone

Ozone, a naturally occurring configuration of three oxygen atoms, is a reliable, clean oxidizing agent with a powerful microbicidal effect against bacteria, viruses, fungi, and protozoa [123,124]. Because ozone can dissolve within solution or be applied in gaseous form, it has been used widely in recent decades. In the disinfection processes, ozone is used in its gaseous or aqueous form depending on the type of decontaminated surfaces. Ozone gas may be used for the disinfection of hospital rooms or transport vehicles, whereas dissolved ozone may be used in water treatment and food disinfection. For wastewater treatment, ozone is a substantial disinfectant that can enhance biological water quality in less time and at a lower concentration with higher efficacy [125]. However, the presence of organic matter may lead to the lower efficacy of decontamination [126]. Moreover, both forms of ozone must be administrated with caution to prevent harm to personnel when inhaled [127].

As a strong oxidizing agent, ozone reacts with the cytoplasmic membrane, thereby breaking lipid components at various bond sites, to inactivate microorganisms [128,129]. In the case of viruses, ozone damages viral capsids, hindering their infectivity to new cells by peroxidative reactions. Enveloped viruses such as coronaviruses might be more sensitive to ozone than non-enveloped viruses due to the interaction of ozone with the lipid layer envelopes [130].

One study showed that a high concentration of ozone (27.73 ppm) inactivated SARS-CoV in 4 min. The medium (17.82 ppm) and low (4.86 ppm) concentrations could also inactivate SARS-CoV with different speeds and efficacy [131]. Hudson et al. reported that the maximum anti-viral efficacy of ozone required a short period of high humidity (>90% relative humidity) after the attainment of the peak ozone gas concentration (20–25 ppm). Mouse coronavirus (MCoV) on different surfaces (glass, plastic, and stainless steel) and in the presence of biological fluids was inactivated by ozone by at least 3 $\log_{10}$ in the laboratory and in simulated field trials [132,133]. Here, we summarized the data of the virucidal activity of ozone water (not gas) against SARS-CoV-2 due to the different experimental methods with other chemical disinfectants (Table 6).

Table 6. The virucidal activity of ozone against SARS-CoV-2.

Product/Active Ingredient	Production Type	Concentration	Disinfection Phase	Contact Time	Reduction of Viral Infectivity ($\log_{10}$)	Reference
Ozone water	Disinfection solution	18, 36 mg/L	Suspension test	1 min	>3 *	[134]
Ozone water	Disinfection solution	0.2–0.8 mg/L	Suspension test	1 min	2	[135]

* No viable virus remained.

Hu et al. implied that an ozone concentration exceeding 18 mg/L could reduce vital SARS-CoV-2 to an undetectable level effectively within 1 min [134]. However, further studies are needed to evaluate the disinfection efficacy of ozone water in real-world conditions, such as the impact of organic material, different surfaces, etc. Martins et al. showed a 2 $\log_{10}$ reduction in the SARS-CoV-2 titer, but no reduction in genome quantification, upon 1 min exposure to ozone water [135]. Further testing, such as using higher ozone concentrations, may help develop the optimal concentration for the environmental disinfection of SARS-CoV-2. In addition, the results of Skowron et al. showed that ozone water improved the microbicidal efficiency of the disinfectant regardless of the disinfectant type, helped to reduce the use of disinfectant concentrations, and limited the increase in the microbial resistance to disinfectants [124].

Ozone water is eco-friendly, has microbicidal properties, and shows a synergistic effect of a biocidal action with other chemical disinfectants. Taken together, ozone water offers