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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, by ClO_2 is caused by damage in the 5′ noncoding region within the genome, which is necessary for the formation of new virus particles within the host cell [92].

At present, there are several studies on the virucidal activity of ClO_2 toward viruses including SARS-CoV-2. For instance, researchers achieved 5 logs of viral titer reduction using pure ClO_2 at 80 ppm against SARS-CoV-2 in a suspension for as little as 10 s [78]. Another study followed the ASTM 2197-17 standard and showed that ClO_2 at a lower concentration of 100 ppm did not fare as effectively against SARS-CoV-2 when dried on a hard non-porous surface, with only a 1.39 $\log_{10}$ reduction after a full 10 min of exposure; however, increasing the concentration to 500 ppm produced more favorable results [30]. The possible reasons for this discrepancy are that the study that inactivated SARS-CoV-2 at lower concentrations of ClO_2 used a suspension test, reduced the protein content, used greater volumes of ClO_2, and had relatively less virus. These factors illustrate the importance of comparing the efficiencies of biocides and their practical use under real-world conditions.

When SARS-CoV-2 viruses were treated with the same concentration of ClO_2 or sodium hypochlorite (24 ppm), ClO_2 reduced the viral titer to below the detection limit ($\leq$2.2 $\log_{10}$ $TCID_{50}$/mL) in 10 s in the presence of 0.5% FBS (fetal bovine serum) and by >4 $\log_{10}$ $TCID_{50}$ in 30 s in the presence of 1.0% FBS. By contrast, 24 ppm of sodium hypochlorite inactivated only 99% or 90% SARS-CoV-2 in 3 min under similar conditions. This suggests that ClO_2 is a much more powerful disinfectant than sodium hypochlorite, especially when organic matter is present in the contaminants.

In addition, it has also been demonstrated that ClO_2 can denature proteins by the oxidative modification of tryptophan and tyrosine residues [93]. Various mutant strains of SARS-CoV-2 have a mutation in asparagine at position 501 to tyrosine (N501Y) in the spike protein, which is also responsible for receptor binding, and ClO_2 might inactivate these novel mutants efficiently. Taken together, these observations might point to ClO_2 being more useful than sodium hypochlorite for inactivating SARS-CoV-2.

Many factors have been found to exert great impacts on virus inactivation rates, including ClO_2 dosage, pH, and temperature. The virus inactivation rates in ClO_2 disinfection increase rapidly with increasing pH and temperature [94].

Overall, chlorine compound-based disinfectants have held a predominant position as reliable disinfectants because they have many of the properties of an ideal disinfectant, including a broad antimicrobial spectrum, rapid action, reasonable persistence in treated potable water, ease of use, solubility in water, relative stability both in its concentrated form and when diluted, relative nontoxicity to humans at use concentrations, a lack of poisonous residuals (reduced predominantly to chloride as a result of its oxidizing action of inorganic and organic compounds), its action as a deodorizer, being colorless, nonflammable, and nonstaining, in addition to having a low cost [95]. Moreover, chlorinated disinfectants can destruct viral nuclear acid by the formation of chloramines and nitrogen-centered radicals or the degradation of the 5′ noncoding region of the viral genome [94,96]. Wu et al. reported that chlorine disinfectant (trichloroisocyanuric acid) could destroy SARS-CoV-2 RNA after 2–3 h of exposure [58]. The disadvantages include the fact that it could cause irritation to mucous membranes; it has the potential to interact with some chemicals, resulting in the formation of toxic chlorine gas; there is an odor when it is used in concentrated forms; it has deleterious effects on some metals; and it has decreased efficacy in the presence of an organic load. Therefore, the cleaning and removal of organic matter before disinfection is recommended. In addition, a biocide's pH and total chlorine availability have the greatest influence on biocidal efficacy. With the COVID-19 pandemic ongoing, there are limited available laboratory data on the efficacy of the chlorinated disinfectants of SARS-CoV-2. It is necessary to determine more precise times-to-inactivation and efficiencies that are used in practice under real-world conditions.