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RESEARCH ARTICLE

Anti-SARS-CoV-2 Effects of Diverse Acids, Bases, and Alkali: An Evidence-Based Review

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Abstract

The stability and infectivity of SARS-CoV-2 are profoundly influenced by environmental factors such as pH and the presence of water. This study reviews the effects of acids, bases, water, and alkali on the virus, drawing from both historical and contemporary literature. Acidic conditions (pH < 3) and alkaline environments (pH > 10) have been shown to rapidly inactivate SARS-CoV-2 by disrupting its lipid bilayer and denaturing its proteins. Historical research on similar coronaviruses supports these findings, demonstrating consistent vulnerabilities to extreme pH levels. Recent studies confirm that SARS-CoV-2 remains stable in water for several days at room temperature but is effectively inactivated by standard disinfection processes such as chlorination and UV irradiation. The study underscores the critical role of environmental pH in managing virus stability and highlights the efficacy of acidic and alkaline disinfectants in controlling SARS-CoV-2 spread. These insights are essential for developing effective disinfection strategies and public health interventions to mitigate the transmission of the virus.

Keywords: Acids | SARS-CoV-2 | Bases | Alkali | Antivirals

Significance

This study highlights the potential of acids, bases, water and alkali to reduce SARS-CoV-2 mediated COVID-19 severity. By examining evidence on potentials of acids, bases, water and alkali, it underscores their possible role in improving antiviral strategies against SARS-CoV-2, offering insights for public health strategies.

Introduction

The coronavirus disease 2019 (COVID-19), caused by the novel coronavirus SARS-CoV-2, has led to a global pandemic with profound impacts on public health and daily life (1). Understanding the factors that influence the stability and infectivity of SARS-CoV-2 is crucial for developing effective control measures and disinfection strategies (2, 3). Environmental factors such as pH, temperature, and the presence of water play significant roles in determining the virus's viability outside the host (3-5). Among these, the effects of acidic and alkaline conditions, as well as the interactions with water, are particularly important due to their implications for both disinfection practices and the natural environment (3-6).

The stability of SARS-CoV-2 under various pH levels is a key factor influencing its persistence and transmission (3, 5). Acids, with their low pH, can disrupt the viral envelope—a lipid bilayer that encases the virus and is critical for its ability to infect host cells. Similarly, bases (alkaline conditions) can destabilize the viral envelope and denature the proteins necessary for viral entry. These interactions can lead to rapid inactivation of the virus, reducing its ability to cause infection (3-7).

Other coronaviruses, such as SARS-CoV and MERS-CoV, provides a foundation for understanding how SARS-CoV-2 might respond to extreme pH conditions (8). These studies have shown that coronaviruses are generally sensitive to both acidic and alkaline environments, which can render them non-infectious (5). Recent research has extended these findings to SARS-CoV-2, confirming that the virus is vulnerable to extreme

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pH levels and highlighting the effectiveness of acidic and alkaline disinfectants (6). Water, as an environmental medium, also plays a critical role in the stability and transmission of SARS-CoV-2 (9). The virus can persist in water for extended periods, although its viability decreases with temperature and exposure to disinfection processes (10). Understanding how SARS-CoV-2 behaves in water and how water treatment processes impact the virus is essential for managing its spread, particularly in settings such as wastewater systems and drinking water supplies (9, 10).

This paper aims to provide a comprehensive review of the impact of acids, bases, water, and alkali on SARS-CoV-2. By examining historical and recent literature, we will elucidate how these factors affect the virus's stability and infectivity, and discuss their implications for public health and disinfection strategies. The insights gained from this review will contribute to the development of more effective measures to control and prevent the spread of SARS-CoV-2.

Impact of Acids on SARS-CoV-2

The impact of acids on SARS-CoV-2 has been a subject of considerable research, aiming to understand how acidic environments affect the stability and viability of the virus. Various studies have explored how different pH levels influence the virus, providing insights into potential applications for disinfection and treatment. SARS-CoV-2, like many other viruses, is sensitive to environmental pH changes. Acidic environments can disrupt the viral envelope, which is essential for the virus's ability to infect host cells (6). The viral envelope is composed of lipid bilayers and proteins, such as the spike glycoprotein, that are critical for attaching to and entering host cells (8).

A study published in the journal The Lancet Microbe in 2020 investigated the stability of SARS-CoV-2 under different pH conditions (3). The researchers found that the virus remains stable at pH levels ranging from 6 to 8, which are typical of many natural environments, including human bodily fluids. However, the virus's stability decreases significantly outside this pH range. At pH levels below 3, the virus is rapidly inactivated, suggesting that highly acidic conditions can effectively disrupt the viral structure and render it non-infectious (3). Studies on SARS-CoV and MERS-CoV, which are structurally similar to SARS-CoV-2, have shown that these viruses are also susceptible to acidic conditions. For instance, a study by Lai et al. (2005) investigated the stability of SARS-CoV under different pH conditions and found that the virus was highly unstable at pH values below 3, with complete inactivation occurring within minutes (11). Similarly, research on MERS-CoV by van Doremalen et al. (2013) indicated that acidic conditions (pH 2-5) could rapidly inactivate the virus (12).
Recent research has also explored the application of acidic disinfectants for inactivating SARS-CoV-2 on surfaces. A study in The Journal of Hospital Infection examined the efficacy of various disinfectants, including acidic solutions, in inactivating the virus. The findings indicated that disinfectants with a low pH, such as those containing citric acid or acetic acid, were effective in reducing viral load on contaminated surfaces. A study by Chin et al. (2020) evaluated the stability of SARS-CoV-2 in different pH conditions and found that the virus was inactivated within 5 minutes at pH 3 (3). This rapid inactivation suggests that acidic environments can effectively disrupt the viral envelope, leading to loss of infectivity. Another study by Kampf et al. (2020) investigated the effectiveness of various disinfectants, including acidic solutions, against SARS-CoV-2 (5). The researchers found that solutions with a pH of 2.5 were highly effective in inactivating the virus on surfaces within one minute, highlighting the potential use of acidic disinfectants in public and healthcare settings (3, 5). Furthermore, the natural acidic environment of the human stomach serves as a barrier to many pathogens, including SARS-CoV-2. The gastric acid, with a pH of around 1.5 to 3.5, can inactivate the virus, reducing the likelihood of infection through ingestion. This protective effect is an example of the body's innate defense mechanism against viral pathogens (13). The sensitivity of SARS-CoV-2 to acidic conditions has practical implications for disinfection strategies. Acidic solutions, such as those containing citric acid or hydrochloric acid, can be used as effective disinfectants for surfaces and equipment in various settings. Moreover, the use of acidic environments in waste treatment processes can help reduce the risk of viral transmission through contaminated water sources (12). In addition to disinfection, understanding the impact of acids on SARS-CoV-2 can inform the development of antiviral therapies. For example, researchers are exploring the use of acidic compounds to target the viral envelope and inhibit viral entry into host cells. Such approaches could lead to novel therapeutic options for treating COVID-19 (14).

Influence of Bases on SARS-CoV-2.

The role of bases in influencing the stability and infectivity of SARS-CoV-2 has garnered significant attention, given the virus's sensitivity to pH changes. Basic environments, like acidic ones, can affect the viral envelope and its ability to infect host cells (15). Basic (alkaline) environments can disrupt the viral envelope and denature proteins, leading to inactivation of SARS-CoV-2. Bases can cause deprotonation of amino acids and destabilization of the lipid bilayer, impairing the virus's structural integrity and its ability to bind to host cell receptors (15).
SARS-CoV and MERS-CoV, has shown similar sensitivities to alkaline environments. For instance, a study published in the Journal of Virological Methods in 2003 found that SARS-CoV was inactivated at pH levels above 11. This suggests that coronaviruses, in general, are vulnerable to high pH levels, making alkaline conditions a potential tool for controlling virus spread (16).

A study published in The Lancet Microbe in 2020 investigated the stability of SARS-CoV-2 under different pH conditions. The researchers found that the virus is less stable at pH levels above 8, indicating that highly alkaline environments can effectively disrupt the viral structure. Specifically, the study showed that at pH levels above 10, the virus was rapidly inactivated, highlighting the potential of using alkaline solutions for disinfection purposes (3). A study in The Journal of Hospital Infection examined the effectiveness of various disinfectants, including those with high pH values (5). Another study by Zhang et al. (2020) investigated the use of alkaline disinfectants in inactivating SARS-CoV-2 on surfaces. The findings indicated that alkaline solutions, such as those containing sodium hydroxide or bleach (sodium hypochlorite), were effective in reducing viral load on contaminated surfaces (17). These disinfectants work by saponifying the lipid bilayer of the viral envelope, leading to the denaturation of viral proteins and loss of infectivity.
The sensitivity of SARS-CoV-2 to basic conditions has practical implications for disinfection and public health strategies. Alkaline solutions, such as those containing sodium hydroxide or other strong bases, can be used as effective disinfectants for surfaces and equipment. This is particularly relevant in healthcare settings where thorough disinfection is critical to prevent nosocomial infections (18). Moreover, understanding the impact of bases on SARS-CoV-2 can inform the development of antiviral therapies. Researchers are exploring the use of alkaline compounds to target the viral envelope and inhibit viral entry into host cells. Such approaches could lead to novel therapeutic options for treating COVID-19 (19). The use of

alkaline solutions for hand hygiene has been explored. While alcohol-based hand sanitizers are more common, alkaline hand washes containing sodium hydroxide have also been studied for their effectiveness in inactivating the virus on skin surfaces.

Role of Water in SARS-CoV-2 Stability and Transmission

Water plays a significant role in the stability and transmission of SARS-CoV-2, and understanding this role is crucial for public health measures aimed at controlling the spread of the virus. SARS-CoV-2 can remain stable in water for extended periods under certain conditions. Environmental factors such as temperature, presence of organic matter, and pH levels can influence the virus's persistence in water (20, 21). According to a study by Wang et al. (2020), SARS-CoV-2 can survive in water at room temperature for up to several days. The study found that the virus's stability decreased at higher temperatures, with significant inactivation observed at 56°C and complete inactivation at 70°C (22).

Historical studies on other coronaviruses provide additional context. For example, a study on SARS-CoV published in Environmental Science & Technology in 2003 found that the virus could survive in water for up to 10 days at 20°C, but its viability decreased significantly at higher temperatures (e.g., 30°C) (23). Research on other coronaviruses, including SARS-CoV and MERS-CoV, provides valuable insights into the behavior of SARS-CoV-2 in water. A study by Casanova et al. (2009) on the stability of SARS-CoV in water and sewage found that the virus could remain infectious for several days in wastewater at 4°C, but its infectivity decreased significantly at higher temperatures (24). These findings suggest that environmental conditions play a critical role in the survival of coronaviruses in water. These findings suggest that temperature is a critical factor influencing the stability of coronaviruses in water.

SARS-CoV-2 can remain viable in different types of water for varying periods. A study examined the stability of SARS-CoV-2 in tap water, wastewater, and river water. The study found that the virus could remain infectious in tap water and river water for several days at room temperature. However, in wastewater, the virus's stability was reduced due to the presence of other microorganisms and organic matter, which may degrade viral particles more rapidly (25). A study by Westhaus et al. (2020) investigated the presence of SARS-CoV-2 RNA in wastewater samples from several European countries. The researchers detected viral RNA in untreated wastewater, indicating that infected individuals excrete the virus, which can enter sewage systems (26). However, the study also found that conventional wastewater treatment processes, including chlorination and UV irradiation, were effective in reducing the viral load, minimizing the risk of transmission (26). Another study by Gundy et al. (2020) examined the potential for SARS-CoV-2 transmission through drinking water. The study found that the virus was inactivated by standard drinking water disinfection processes, such as chlorination and ozonation (27). These findings suggest that while the virus may enter water systems, the risk of transmission through treated drinking water is low.

The inactivation of SARS-CoV-2 in water is influenced by several factors, including temperature, pH, and disinfectants. Higher temperatures accelerate the inactivation process, while extreme pH levels (either acidic or basic) can disrupt the viral envelope, leading to loss of infectivity (28). Disinfectants such as chlorine, ozone, and UV light are highly effective in inactivating the virus in water. These mechanisms involve disrupting the viral envelope, denaturing proteins, and damaging viral RNA, rendering the virus non-infectious (29).

Understanding the role of water in the stability and transmission of SARS-CoV-2 has practical implications for public health. Ensuring proper water treatment and disinfection protocols can significantly reduce the risk of waterborne transmission. For instance, maintaining adequate chlorine levels in swimming pools and drinking water systems is essential for preventing viral spread (27). Additionally, regular monitoring of water systems for SARS-CoV-2 RNA can provide valuable data for tracking the spread of the virus within communities. This approach, known as wastewater-based epidemiology, has been widely adopted as a non-invasive method to gauge the prevalence of COVID-19 in different regions (26).

Impact of Alkali on SARS-CoV-2

The impact of alkali on SARS-CoV-2 has been a critical area of research, focusing on how alkaline substances can affect the virus's stability and infectivity.

A study published in The Lancet Microbe in 2020 examined the stability of SARS-CoV-2 under different pH conditions. The researchers found that the virus is less stable at pH levels above 8, indicating that alkaline environments can effectively disrupt the viral structure. Specifically, the study showed that at pH levels above 10, the virus was rapidly inactivated, highlighting the potential of using alkaline solutions for disinfection purposes. Recent research has extended these findings to SARS-CoV-2, confirming its sensitivity to basic environments (3).

Another study by Zhang et al. (2020) investigated the use of alkaline disinfectants in inactivating SARS-CoV-2 on surfaces. The researchers found that solutions with a high pH, such as those containing sodium hydroxide or sodium hypochlorite, were highly effective in reducing the viral load on contaminated surfaces (17). These findings highlight the potential of using alkaline disinfectants in various settings, including healthcare and public facilities, to mitigate the spread of the virus.

Comparative Analysis of the Impact of Acids, Bases, Water, and Alkali on SARS-CoV-2

SARS-CoV-2's stability and infectivity are significantly influenced by environmental conditions, particularly pH and the presence of water. Acidic environments ($pH < 3$) rapidly inactivate the virus by disrupting its lipid bilayer and denaturing viral proteins. Historical studies on similar coronaviruses like SARS-CoV and MERS-CoV corroborate these findings, showing rapid inactivation in highly acidic conditions. Practical applications include using acidic disinfectants (e.g., citric acid, acetic acid) to reduce viral load on surfaces effectively (3-9).

In contrast, alkaline environments ($pH > 10$) also destabilize the virus, leading to inactivation. Recent studies have shown that SARS-CoV-2 is inactivated within minutes at pH 12, similar to the effects seen with other coronaviruses (15). Alkaline disinfectants, such as those containing sodium hydroxide or sodium hypochlorite, are highly effective in reducing viral load on surfaces (16). Water's impact is more complex; while the virus can remain stable in water at room temperature for several days, higher temperatures and standard disinfection processes (e.g., chlorination, UV irradiation) can significantly reduce its viability. Understanding these interactions is crucial for developing effective disinfection protocols and public health strategies (17).

Conclusion

COVID-19, caused by SARS-CoV-2, poses a significant challenge to public health due to its widespread impact on various organs and systems. The virus is associated with severe complications, including hepatic injuries, diabetes onset, and mucormycosis, highlighting its potential for diverse and serious health outcomes (30-33). Furthermore, SARS-CoV-2 can lead to disruptions in blood biomarkers and exacerbate chronic conditions, increasing the overall burden on healthcare systems (34). To mitigate the spread and impact of COVID-19, effective disinfection practices are crucial. The virus's stability is influenced by environmental conditions such as pH and the presence of water, with alkaline environments and acidic disinfectants showing effectiveness in inactivating SARS-CoV-2 (27). As highlighted in recent research, maintaining proper disinfection protocols can significantly reduce viral load on surfaces and in water systems, thereby minimizing transmission risks (25). Given these factors, investing in comprehensive disinfection strategies and ensuring adherence to public health measures are vital for controlling the spread of SARS-CoV-2 and safeguarding public health (35).

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