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Current Opinion in
Colloid & Interface Science

The viability of SARS-CoV-2 on solid surfaces

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Abstract

The COVID-19 pandemic had a major impact on life in 2020 and 2021. One method of transmission occurs when the causative virus, SARS-CoV-2, contaminates solids. Understanding and controlling the interaction with solids is thus potentially important for limiting the spread of the disease. We review work that describes the prevalence of the virus on common objects, the longevity of the virus on solids, and surface coatings that are designed to inactivate the virus. Engineered coatings have already succeeded in producing a large reduction in viral infectivity from surfaces. We also review work describing inactivation on facemasks and clothing and discuss probable mechanisms of inactivation of the virus at surfaces.

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Current Opinion in Colloid & Interface Science 2021, **55:**101481

This review comes from a themed issue on **Hot Topic: COVID-19**

Edited by **Reinhard Miller** and **Libero Liggieri**

For complete overview about the section, refer Hot Topic: COVID-19

https://doi.org/10.1016/j.cocis.2021.101481

Keywords

COVID-19, SARS-CoV-2, Surface, Coating, Solid, Coronavirus.

Introduction

Severe acute respiratory coronavirus-2 (SARS-CoV-2) is the virus that causes COVID-19 and has been responsible for more than 100 million cases and 2 million deaths as of February 2021 (COVID-19 Dashboard by the Center for Systems Science and Engineering at Johns Hopkins University, https://coronavirus.jhu.edu/map.html). SARS-CoV-2 is transmitted through infected respiratory droplets and aerosols generated by a diseased person [1,2]. Respiratory droplets and aerosols can be generated when a person sneezes, coughs, speaks, or breathes [3]. An individual is infected by the virus through nasal or oral inhalation of the infected droplets or aerosols and then attachment of the virus to the epithelial membrane [2]. The pathway to infection is not fully understood but is thought to be via inhalation of either respiratory droplets or aerosolized virus (WHO Transmission of SARS-CoV-2: implications for infection prevention precautions, https://www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-infection-prevention-precautions). For this reason, health officials have advised that individuals should avoid poorly ventilated public places [4], wear a mask in public places, and increase distance between other individuals [3,5].

The possibility of infection via solid surfaces has also been considered. In this scenario, a droplet that contains virus lands on and contaminates an inanimate object. The contaminated object is called a fomite. The next user touches the fomite, and the virus is transferred from the fomite to the user's hand. Infection can occur if the person then touches their nose, mouth, eyes, or ears (Figure 1). A preprint (Behzadinasab et al., medRxiv doi: 10.1101/2021.04.24.21256044) confirmed that SARS-CoV-2 can be transferred from fomites to artificial skin.

A study on Golden Hamsters showed that the virus can be indirectly transmitted through fomites [6], but we are unaware of a study directly showing fomite transmission in humans. The WHO not only states that "fomite transmission is considered a likely mode of transmission for SARS-CoV-2" (WHO Transmission of SARS-CoV-2: implications for infection prevention precautions. https://www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-infection-prevention-precautions), but also notes that "People who come into contact with potentially infectious surfaces often also have close contact with the infectious person, making the distinction between respiratory droplet and fomite transmission difficult to discern" (WHO Transmission of SARS-CoV-2: implications for infection prevention precautions. https://www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-infection-prevention-precautions). Modeling of outbreaks suggests that transmission via fomites may contribute up to 25% of deaths during periods of lockdown [7].

Infection via fomites depends on the longevity of SARS-CoV-2 on a solid because an infectious dose clearly must survive until following users contact the solid. The longevity of SARS-CoV-2 depends on the solid material, CoV-2 within 30 min. Additionally, the biocidal ability of the fabrics remained after 50 washes using a standardized home laundry test protocol.

These modified textiles have been shown the ability to be very robust, long lasting, breathable, and capable of inactivating a wide array of microbes very quickly. Since users inhale though the mask, a key element of these active masks will be showing the lack of toxicity of the active material.

Future perspectives

Characterization of surfaces

A large fraction of stability studies of SARS-CoV-2 to date have been on common substances such as paper and steel. These previously conducted studies are undoubtedly valuable sources of information; however, we suggest that future studies should contain a thorough description and characterization of the test solids. The inclusion of such information would help to understand the mechanism. At minimum, the exact source of the test surface and the cleaning procedure should be specified.

The surface chemistry can be measured by surface-selective techniques such as X-ray photoelectron spectroscopy and energy-dispersive X-ray spectroscopy and Fourier-transform infrared spectroscopy, which are widely available in collaborative efforts or in service centers. Surface morphology studies can be carried out through scanning electron microscopy, optical microscopy, and atomic force microscope. The shape and size of particles and porous nature of the samples can be revealed by studying of surface topology. If the solid is porous, Brunauer—Emmett—Teller analysis can specify the surface area associated with the porosity.

The contact angle measurements also provide useful information on the wettability of the droplet on the surface. One complication here is that a natural viral suspension produced by an infected individual may contain many different ingredients depending on its source and that these ingredients may affect the wettability. Surface characterization in future studies will enable discovery of the correlation between surface properties and inactivation and help to determine the mechanism. It will lead the way to the design of optimal surfaces to reduce the half-life of the virus on the solid.

Porosity

In general, porosity is very important for future coatings because it (1) can trap the virus, (2) allows for a greater area of active ingredient, (3) the internal structure is protected by the overlying structure from damage by abrasion, and (4) diffusion distances between the active ingredient and the virus can be made very small with small pore sizes. Several papers have noted the correlation between effectiveness and porosity. At this point only one, by Hosseini et al. [44], has shown that an increased pore volume of CuO led to a decrease in the viral titer of SARS-CoV-2.

Active ingredients

To date, active ingredients have been based mainly on prior work on other viruses. There have been no specific active ingredients that have been targeting specifically at SARS-CoV-2. Given the efforts to find drugs that target specific portions of SARS-CoV-2, we may expect that some of these will be incorporated into future surface coatings.

Multiple organisms

The deployment of vaccines the COVID-19 pandemic will, hopefully, mean that SARS-CoV-2 will have less impact on life beyond 2021. But the lessons learned from coatings can still be applied to other organisms, such as bacteria, fungi, and other viruses. We expect that multimicrobe coatings will continue to be fruitful areas of research following public sensitivity to microbial diseases.

Transfer from surfaces to humans

To date, the focus has been on surfaces that inactivate SARS-CoV-2; however, to cause infection, the virus must be transferred to the respiratory tract. To reach the respiratory tract, there needs to be contact transfer from the solid to hands and from hands to the face. Transfer of virus through this chain of contacts is an interesting future area of research.

The mechanism of the inactivation of SARS-CoV-2

Studies of the mechanism of action of new antiviral materials should provide valuable insight into the selection of new antimicrobial agents and the design and fabrication of improved antimicrobial surfaces.

Summary

SARS-CoV-2 has been found on many public surfaces during the pandemic, and the lifetime of infective virus on solids is as long as a week under laboratory conditions. To diminish the window of opportunity for infection from surfaces, several researchers, including those from our group, have sought to prepare coatings that rapidly inactivate SARS-CoV-2. Such surfaces are already capable of causing a 99.9% reduction in 1 h [16] or cause almost immediate loss of infectivity through adsorption into porous coatings [44].

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: William Ducker is a part owner of a company that plans to make surface coatings.