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Abstract

The Covid-19 coronavirus, SARS-CoV-2, is inactivated much faster on paper (3h) than on plastic (7d). By classifying materials according to virus stability on their surface, the following list is obtained (from long to short stability): polypropylene (mask), plastic, glass, stainless steel, pig skin, cardboard, banknote, cotton, wood, paper, tissue, copper. These observations and other studies suggest that SARS-CoV-2 may be inactivated by dryness on water absorbent porous materials but sheltered by long-persisting micro-droplets of water on waterproof surfaces. If such physical phenomenons were confirmed by direct evidence, the persistence of the virus on any surface could be predicted, and new porous objects could be designed to eliminate the virus faster.

Keywords

enveloped virus, coronavirus, inactivation, persistence, surface, mechanisms

Introduction

The Covid-19 coronavirus, SARS-CoV-2, is inactivated much faster on paper than on plastic: Three hours after being laid on paper, no virus can be detected. In contrast, the virus can still infect cells seven days after being laid on plastic. By classifying materials according to SARS-CoV-2 stability on their surface, the following list is obtained (from long to short stability): polypropylene (mask), plastic, glass, stainless steel, pig skin, cardboard, banknote, cotton, wood, paper, tissue, copper [1–4].

The tested items, the methods and criteria are not exactly the same in the above cited studies. Also, the decay of infectious virus is biphasic with long persistence of few virus on smooth surface [1]. Several lists can thus be obtained, depending on the ranking criteria. However, differences between these lists are marginal, involve mostly the median items (e.g., cardboard, cotton, wood), and the variations do not change what follows.

Persistence of other enveloped viruses on surfaces also depends on the material. SARS-CoV-1 behaves very much like SARS-CoV-2 [2]. Influenza virus also survives longer on plastic and stainless steel (24-48h) than on on paper and tissue (6-8h) [5].

- Pragmatically, these differences suggest that, in order to reduce the spread of virus via fomites, paper sheets and bags should be used instead of plastic to wrap, cover and carry objects (books, food, furniture). Similarly, copper alloy should be used instead of stainless steel to make handles and door knobs, as already reported [6].

- Scientifically, such differences in survival time are puzzling: Why would the virus be "killed" by certain materials, and conversely be "protected" by others? Absorbent products that blotter moisture seem to inactivate the virus. In contrast, smooth and waterproof materials, but copper, seem to protect the virus. Would the virus be killed by lack of water? Such a simple explanation is hard to believe, since a virus is not metabolically active and should therefore not need water. So how could a virus die of "dryness"? This short review suggests a hypothesis explaining why SARS-CoV-2 survives longer on plastic than on paper and examines published evidence on this questions.

Hypothesis

Dryness would inactivate SARS-CoV-2 virus on paper and other porous solids. Conversely, droplets of water remaining on waterproof surfaces would protect the viruses from dryness.

Evaluation of the hypothesis

Firstly, the common belief that viruses do not contain water was challenged long ago. In 1950 Sharp & Beard established by experiments of sedimentation of influenza virus with deuterated water that these viruses contain 60% of water: water corresponds to 150-230% of their dry weight, depending on method and on influenza strain A, B or swine [7]. Since coronavirus and influenza virus are both "enveloped" in a lipid membrane they take from their host cell, one may think that they both take some cytoplasm and that coronavirus also contains approximately two third of water.

Secondly, Cox reported 30 years ago that dehydration could inactivate enveloped viruses: this inactivation would occur by structural changes of the bilayer membrane, that would need water on its both sides to remain stable. Direct contact of enveloped virus with dry air would also lead to oxidation of lipids and Maillard reactions of proteins [8,9]. Non-porous surfaces, compared with porous surfaces, would be better at preserving coronavirus viability because they do not draw moisture away from adsorbed viruses. Improved virus persistence would be due to the ability of a surface to maintain a moist microenvironment [10]. However, we could not find solid evidence to support these assumptions, and no work has explicitly investigated the physicochemical mechanisms underlying why some surfaces support longer virus persistence.

Thirdly, water droplets may stay for days on plastic, glass and stainless steel, not on copper. Using photos taken under a microscope every hour Kumar et al. demonstrated that droplets condensed from human breath first shrink rapidly on a smooth surface leaving residues of a few micrometers [11]. Then, these resulting micro-drops persist without further decrease in size for more than 24 hours on plastic and glass. They are smaller on stainless steel than on plastic and glass, and they quickly disappear from a copper surface. These micro-drops are 10 to 100 times larger than a coronavirus, which is enough to shelter the virus particles, insulating them against heat and dryness. Kumar et al. explain fast disappearance of drops on copper surface by its high thermal conductivity, while drops are protected from the subsurface heat on more insulating surfaces like stainless steel, glass and plastic [11]. The disappearance of drops on paper or cotton was not studied, but we can assume that they quickly disappear from such absorbent supports, leaving viruses exposed and unprotected to dry air, thus leading to their inactivation.

However, the hypothesis that dryness would inactivate SARS-CoV-2 seems in contradiction with experimental studies showing higher reduction in coronaviruses number at 80% relative humidity than at 20% humidity [12,13] and with epidemiological studies suggesting that wet climates reduce Covid-19 transmission [14]. The effect of high humidity is not the scope of this article. Briefly, the wet conditions appear to discourage aerosol transmission of influenza virus, but may increase virus survival in droplets on surfaces [15]. Moreover, 90% of all Covid-19 cases in the world were detected in places where absolute humidity was between 4 and 8 g/m^3 [16]. SARS-CoV-2 transmission thus seems reduced in both wet and dry climates, the latter being compatible with our hypothesis.

These studies thus support the hypothesis that dryness inactivates SARS-CoV-2 virus on paper and other cellulose-based porous solids. Conversely, the droplets of water that stay for days on plastic and other waterproof surfaces would protect the viruses. An alternative hypothesis would be that cellulose chemically inactivates the virus: we think it is unlikely. In addition let us examine below two outliers at both ends of the above cited list: copper and face masks.

Outliers

Copper is an outlier in the above cited list of materials. It is the only smooth and waterproof surface on which the virus persists less than a day. One may accept Kumar et al. explanation that copper conductivity leads to the fast evaporation of protective droplets. However, copper also holds antiseptics properties on influenza virus and common cold coronavirus 229E. Exposure to copper destroys the viral genome, disintegrates envelope and disperses spikes. Cu(I) and Cu(II) moieties are responsible for the inactivation, which is enhanced by reactive oxygen species generation on alloy surfaces [6][17]. Silver has not yet been tested with SARS-CoV-2. Like copper, it has a high thermal conductivity and is a powerful antiseptic. We therefore suggest that the Covid-19 coronavirus is not stable on silver.

Finally, coronavirus persists for a particularly long time on face masks. The mask inner layer is made of a specific plastic material, polypropylene, which holds permanent electrostatic charges and is thus an "electret" [18,19]. The stability of viruses on this material may be linked to the strong bond between the electret and the viral particles (See [20] Fig.3). Virus adsorption on a surface would stabilize them [21]. For instance, survival of viruses in soil is linked to their adsorption onto soil particles [22]. This has not, however, yet been demonstrated for coronavirus on mask electret.

Implications

The direct demonstration of the hypothesis remains however to be done experimentally, notably for porous blotting material like paper. A simple approach to this demonstration would be to test the persistence of SARS-CoV-2 on a range of papers with various blotting ability in dry or moist atmospheres.

Such demonstration would be of scientific interest, regarding the physical mechanisms of disappearance of lipid bilayer enveloped viruses on blotting surfaces. It would also have practical applications.

First, it would make it possible to predict whether the enveloped viruses may persist on materials that have not been tested yet. For instance, our hypothesis predicts that enveloped viruses, should be quickly inactivated on absorbent products like bread crumb, “suede” leather, salt and chalk. Conversely these viruses should be relatively stable on non absorbent products like glossy paper, polished marble or fruit skin, and possibly more stable on wet products like fresh meat.

Finally this would help to design objects and surfaces that eliminate coronavirus faster that paper and tissue. Many materials are more absorbent than paper tissue, for instance super-absorbent polymers from cellulose (e.g., wood pulp, carboxymethylcellulose), from petroleum (e.g., acrylamide, acrylic acid), and mineral desiccant (e.g., silica aerogel, montmorillonite “nano-clay”) [23]. Objects made of, or covered with such material would be expected to reduce the survival of coronaviruses on their surface. Direct spread of saliva, aerosol diffusion, and contact with fomites are three ways of coronavirus spread. The increased use of water absorbent objects might thus reduce the fomite way of Covid-19 spread.

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Conflict of interest statement

The author declares no competing interest.

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