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Review

SARS-CoV-2 Persistence: Data Summary up to Q2 2020

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Abstract: The coronavirus pandemic is causing confusion in the world. This confusion also affects the different guidelines adopted by each country. The persistence of Coronavirus, responsible for coronavirus disease 2019 (Covid-19) has been evaluated by different articles, but it is still not well-defined, and the method of diffusion is unclear. The aim of this manuscript is to underline new Coronavirus persistence features on different environments and surfaces. The scientific literature is still poor on this topic and research is mainly focused on therapy and diagnosis, rather than the characteristics of the virus. These data could be an aid to summarize virus features and formulate new guidelines and anti-spread strategies.

Keywords: COVID-19; virus; epidemiology; surfaces; infection risk; public health; coronavirus; persistence

1. Introduction

1.1. Background

Coronaviruses are responsible for respiratory diseases, from the common cold to severe ones, such as Middle Eastern respiratory syndrome (MERS) and severe acute respiratory syndrome (SARS). They are spherical viruses, covered with a helically symmetrical capsid and a pericapsid crossed by glycoprotein structures that give it the typical 'crown' appearance. The viral genome consists of single-stranded RNA. The Orthocoronavirinae subfamily of the Coronaviridae family includes four coronavirus (CoV) genera: Alpha-, Beta-, Delta- and Gamma-coronavirus. The betacoronavirus is divided into five subgenera. Coronaviruses are capable of infecting both humans and some animal species, these viruses were first identified around the 1960s. Epithelial cells of the respiratory and gastrointestinal tract are those mainly affected by these viruses. To date, seven Coronaviruses are able to infect humans:

- Common human coronaviruses: HCoV-OC43 and HCoV-HKU1 (Betacoronavirus) and HCoV-229E and HCoV-NL63 (Alphacoronavirus); they cause common colds and severe lower respiratory infections
- other human Coronaviruses (Betacoronavirus): SARS-CoV, MERS-CoV and 2019-nCoV (now called SARS-CoV-2).

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is responsible for the Coronavirus disease 2019 (COVID-19). The incubation period of this infectious disease varies from about 2 to 14 days (with some reported cases of 29 days), during this time the patient could be contagious [1,2]. COVID-19 is due to Coronavirus SARS-CoV-2 infection. The new coronavirus was named Coronavirus SARS-CoV-2 by the Coronavirus study group of the International Committee on Taxonomy of Viruses (the commission responsible for classifying and naming viruses) because it was considered to be a "brother" of the virus responsible for SARS (SARS- CoV).

Coronaviruses are common in animal species such as bats and camels, but they can evolve and infect humans; this ability of viruses in the animal world to become pathogenic to humans is called "species jump" or spillover. To date, seven types of human coronavirus have been discovered, the first were identified in the mid-seventies, while the last are recent (SARS-CoV, 2002; MERS-CoV, 2012), up to the new coronavirus SARS-CoV-2 of 2019.

Respiratory droplets are the main way of transmitting the virus; these could pass from one person to another through a sneeze, a cough and direct personal contacts, but also through the hands that if not washed can be contaminated and transmit the virus to others through simple contact (think of a close hand: if the infected person has contaminated hands, he can transfer the virus onto the other's hands, which in turn could become infected by bringing a hand to the mouth, eyes or nose). The suspension of these droplets in the air depends on their size before fall and rest on the floor and surfaces. Careful hygiene, hand washing and personal protective equipment (PPE) use should be considered to limit virus transmission [3–7]. Small airborne droplets represent an infection route, in addition to larger droplets and contact with infected people or contaminated surfaces. Although uncertainties remain regarding the relative contributions of different transmission routes, it could be useful to control environments through engineering ventilation systems. Ventilation, enhanced by particle filtration and air disinfection, could be an appropriate building engineering controls avoiding air recirculation and avoiding overcrowding [8–11].

Recently, the contamination and decontamination of inanimate surfaces has been discussed. Inactivation time of the Sars-CoV-2 on surfaces (liquid, solid or gaseous) is still debated [12–19]. The exposed surfaces to this type of transmission route include:

- Handles and public transport handholds;
- Buttons;
- Mobile phones and electronics;
- Floor [20–26].

It is necessary to consider how the virus could be easily spread in the environment even in the form of an aerosol, and how the latter's precipitation time mainly depends on the size of the droplet as shown in Table 1. Healthcare staff may transmit the viable virus from the floor of one ward to another on their shoes.

One of the most common methods for quantifying the virus is plaque testing, especially with viruses that lyse infected cells. It consists of infecting tissue cultures organized in wells or plates, with dilutions of the sample virus. A first step is to remove the culture medium to facilitate optimal contact between viruses and cells. After a short incubation, the cultures are covered with semi-solid agar. It is about preventing viruses from spreading freely, so it will only infect cells adjacent to those already infected. $TCID_{50}$ (Fifty-percent tissue culture infective dose) quantifies the amount of virus needed to destroy or cause any other type of cytopathic effect in 50% of infected cells or cultures. It is

considered more accurate than previous methods because the concentrations that produce 100% effect can vary widely, and the 50% value is the most accurate [27–31].

Table 1. Sedimentation rate of airborne particles. The new Coronavirus has a diameter of approximately 0.1 µm.

Diameter (µm)	Velocity (m/h)
0.1	0.003
1	0.11
2	0.43
3	0.97
5	2.7
10	10.8
20	42

1.2. Summary and Aim

The aim of this article is share useful data about virus persistence. From this analysis it is possible to state some features; The virus can reach surfaces in the form of an aerosol. Therefore, following nebulisation through people (sneezing or coughing) or electro-medical machinery, surface infection should be considered. Many scientific studies provide us with information on the effectiveness of chemical formulations that allow the inactivation of the virus. In the literature, studies on the persistence of the virus in different environments are still limited, and this creates confusion in the scientific community, in the health sector and in the population. It is important to note that the infectious dose is reduced by about 1/3 after 3 h in the aerosol, while on surfaces such as plastic or stainless steel, it takes respectively 72 and 48 h, until a reduction occurs. The virus appears to be damaged or altered by copper, and this occurs on copper surfaces. The high temperature can interfere with the persistence of the virus in the surfaces, moreover the pH and humidity can play an essential role in the prevention and elimination of the virus. In fact, the virus at 22 °C resists up to 14 days, unlike higher temperatures (70 °C) where it resists for a maximum of 5 min. It is important to briefly report which are the main characteristics of the new coronavirus on the different surfaces. First of all, its $TCID_{50}$ tends to vary depending on different factors. One of these is the material of the surface—in fact, some surfaces have shown antiviral effects, such as copper. It is also necessary to underline that other environmental factors could also influence the persistence of the new coronavirus, for example temperature or humidity. A progressively rising temperature tends to inactivate the virus quickly, a higher humidity rate instead has the opposite effect.

- The study aims to evaluate new coronavirus persistence on different:
  - Surfaces;
  - Temperatures;
  - Humidity conditions;
  - pH.

2. Data Description

2.1. Data Features

Results were singularly analyzed by the authors, and items about viruses' persistence on different surface materials were evaluated and shown as follow:

A table has been designed to show a summary of inherent virus features.

The Table 2 items are as follows:

- Virus: type of investigated virus;
- Authors and Year: authors, reference (according to journal guidelines), and year of publication;
- Investigated Material: investigated material surfaced by the study;
- Time: persistence time of virus;
- Note on Results: additional notes on results.

Table 2. Results of individual studies.

Virus	Authors and Year	Investigated Material	Time	Note on Results
2019-nCoV	Van Doremalen et al. 2020 [32]	aerosols	3 h	Reduction from 103.5 to 102.7 $TCID_{50}$ per liter of air
		plastic	72 h	Reduction from 103.7 to 100.6 $TCID_{50}$ per millimeter
		stainless steel	48 h	from 103.7 to 100.6 $TCID_{50}$ per millimeter
		copper	4 h	No viable SARS-CoV-2
		cardboard	24 h	No viable SARS-CoV-2
2019-nCoV	Chin et al. [33]	Paper	3 h	From 4.76 $TCID_{50}$ at 0 min to 2.18 $TCID_{50}$ at 30 min
		Wood	48 h	From 5.66 $TCID_{50}$ at 0 min to 2.47 $TCID_{50}$ at 6 h
		Cloth	48 h	From 4.84 $TCID_{50}$ at 0 min to 2.25 $TCID_{50}$ at 6 h
		Glass	96 h	From 5.83 $TCID_{50}$ at 0 min to 5.06 $TCID_{50}$ at 6 h
		Stainless Steel	7 days	From 5.80 $TCID_{50}$ at 0 min to 5.24 $TCID_{50}$ at 6 h
		Plastic	7 days	From 5.81 $TCID_{50}$ at 0 min to 4.68 $TCID_{50}$ at 6 h
		Mask (inner layer)	7 days	From 5.88 $TCID_{50}$ at 0 min to 5.01 $TCID_{50}$ at 6 h
		Mask (outer layer)	/	From 5.78 $TCID_{50}$ at 0 min to 4.97 $TCID_{50}$ at 6 h to 2.79 at 7 days
Other coronaviruses	Van Doremalen et al. 2020 [32]	aerosols	3 h	reduction from 104.3 to 103.5 $TCID_{50}$ per liter of air
		plastic	72 h	from 103.4 to 100.7 $TCID_{50}$ per millimeter
		stainless steel	48 h	from 103.6 to 100.6 $TCID_{50}$ per millimeter
		copper	8 h	No viable SARS-CoV-1
		cardboard	8 h	No viable SARS-CoV-1

Table 2. *Cont.*

Virus	Authors and Year	Investigated Material	Time	Note on Results
	Kampf et al. 2020 [34]	paper	5 min up to 5 days	10^5 $TCID_{50}$ per millimeter
		glass	4–5 days	10^4 $TCID_{50}$ per millimeter
		plastic	2–9 days	10^6 $TCID_{50}$ per millimeter
		PVC	5 days	10^3 $TCID_{50}$ per millimeter
		silicon rubber	5 days	10^3 $TCID_{50}$ per millimeter
		surgical gloves (latex)	5 days	10^3 $TCID_{50}$ per millimeter
		disposable gowns	1–2 days	10^5 $TCID_{50}$ per millimeter
	Warnes et al. 2015 [35]	polyfluorotetraethylene (PTFE)	5 days	10^3 $TCID_{50}$ per millimeter
		ceramic	5 days	10^3 $TCID_{50}$ per millimeter
		glass	5 days	10^3 $TCID_{50}$ per millimeter
		stainless steel	5 days	10^3 $TCID_{50}$ per millimeter
		polyvinyl chloride (PVC)	5 days	10^3 $TCID_{50}$ per millimeter
		silicon rubber	3 days	10^3 $TCID_{50}$ per millimeter
		brasses containing copper	<40 min	10^3 $TCID_{50}$ per millimeter
		copper nickels	120 min	10^3 $TCID_{50}$ per millimeter
		zinc	60 min	

Results of individual studies were shown after an accurate analysis in Table 2.

2.1.1. Coronavirus Features

Coronaviruses are positive RNA viruses with a diameter of approximately 80–160 nm. The name of the virus derives from the classical form appreciable in the "corona" transmission electron microscope. The genome is found in the nucleocapsid consisting of a 27–30 kilo base ssRNA + (single stranded RNA-virus with positive polarity) that encodes 7 viral proteins and is associated with protein N. Coronaviruses attach themselves to the cell membrane of target cells thanks to their proteins S interacting with the membrane aminopeptidase N. The coronavirus family has been divided into four distinct genera:

- Alphacoronavirus (α-CoV);
- Betacoronavirus (β-CoV);
- Gammacoronavirus (γ-CoV);
- Deltacoronavirus (δ-CoV).

Coronaviruses were discovered in the 1960s from the nasal passages of patients with the common cold. These viruses were later named Human Coronavirus 229E (HCoV-229E) and Human Coronavirus OC43 (HCoV-OC43). Two other members of this family have been identified (Human Coronavirus NL63, HCoV-NL63, in 2004; Human Coronavirus HKU1, HCoV-HKU1, in 2005) and have been involved in severe respiratory tract infections. There are no vaccines or antiviral drugs considered valid by the scientific community for the prevention or treatment of induced pathologies. A significant percentage of common colds in adults and children are caused by Coronaviruses. Frequently encountered

symptoms are fever and acute adenoiditis with greater incidence during winter and early spring. In many cases, coronaviruses could cause pneumonia, direct viral pneumonia, or secondary bacterial pneumonia; they could also lead to the development of secondary bronchitis, direct viral bronchitis or bacterial bronchitis.

As of January 2020, seven coronavirus strains are known to be able to infect humans:

(1) Human Coronavirus 229E (HCoV-229E);
(2) Human Coronavirus OC43 (HCoV-OC43);
(3) Human Coronavirus NL63 (HCoV-NL63);
(4) Human Coronavirus HKU1 (HCoV-HFU1);
(5) Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV)
(6) Middle Eastern Coronavirus Respiratory Syndrome (MERS-CoV)
(7) Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), responsible for the COVID-19 disease.

(1) Human coronavirus 229E (HCoV-229E) is a species of coronavirus that infects humans and bats. The species belongs to the genus Alphacoronavirus and is the only one of the subgenus Duvinacovirus. It is a single-stranded, positive-sense enveloped RNA virus that enters its host cell by binding to the APN (Membrane alanyl aminopeptidase also known as alanyl aminopeptidase (AAP) or aminopeptidase N) receptor. HCoV-229E is associated with a range of respiratory symptoms, ranging from the common cold to high morbidity outcomes such as pneumonia and bronchiolitis.
(2) The human coronavirus OC43 (HCoV-OC43) is a viral strain of the Betacoronavirus 1 virus, which infects humans and livestock, of the genus Betacoronavirus of the subgenus Embecovirus, as it possesses haemagglutinin esterase (HE) among the surface proteins. It is a single-stranded, positive-sense enveloped RNA virus that enters its host cell by binding to the N-acetyl-9-O-acetylneuraminic acid receptor. Together with the human coronavirus 229E, it is one of the viruses responsible for the common cold
(3) Human coronavirus NL63 (HCoV-NL63) is a species of coronavirus identified in late 2004 in a seven-month-old baby with bronchiolitis in the Netherlands. The virus is a positive-sense monofilament RNA virus that enters its host cell via the ACE2 receptor. The virus originated from infected palm owls and bats. Infection with the virus has been confirmed worldwide, associated diseases include mild to moderate upper respiratory tract infections, severe lower respiratory tract infection, and bronchiolitis, also responsible for gastrointestinal manifestations. Recent data suggest an association of HCoV-NL63 infection with Kawasaki disease, a systemic vasculitis in childhood that can result in coronary artery aneurysms [36]. In the developed world, Kawasaki disease is the most common cause of acquired heart disease in children.
(4) Human coronavirus HKU1 (HCoV-HKU1) is a species of virus originating from infected mice, of!the genus Betacoronavirus, subgenus Embecovirus, as it has the hemagglutinin esterase (HE) gene. In humans, the infection causes upper respiratory disease with symptoms of the common cold, but it can progress to pneumonia and bronchiolitis.
(5) The severe acute respiratory syndrome coronavirus, abbreviated to SARS-CoV (Severe Acute Respiratory Syndrome—Coronavirus), is a viral strain at the origin of the 2003 SARS epidemic. SARS-CoV is one of the positive polarity single-chain RNA viruses (group IV of the Baltimore classification), of the SARS-related coronavirus species, belonging to the genus of Betacoronavirus.
(6) MERS (Middle East Respiratory Syndrome) or coronavirus Middle East respiratory syndrome is a disease caused by the coronavirus MERS-CoV. The virus causing the pathology is a coronavirus similar to the virus causing SARS, but the disease it causes, although similar to SARS, seems to cause greater mortality, in fact, its lethality rate is approximately 34%, while for SARS it is 10%.
(7) The severe acute respiratory syndrome coronavirus 2, abbreviated to SARS-CoV-2 (acronym from severe acute respiratory syndrome coronavirus 2) [1,2], previously named new coronavirus

of 2019 (2019-nCoV [3], or also 2019 nCoV-ARD) [4], is a viral strain of the SARS-related coronavirus/SARS-CoV species, belonging to the genus Betacoronavirus. Already described in the previous chapter.

The signa nCoV generically indicates new species or strains of coronavirus that have never previously been identified in humans [37,38].

2.1.2. Coronaviruses Testing Methods

In the first study Coronavirus aerosols were generated with the use of a three-jet Collison nebulizer and fed into a Goldberg drum to create an aerosolized environment. The inoculum resulted in cycle-threshold values between 20 and 22, similar to those observed in samples obtained from the upper and lower respiratory tract in humans.

Results consisted of 10 experimental condi-tions involving two viruses (SARS-CoV-2 and SARS-CoV-1) in five environmental conditions (aerosols, plastic, stainless steel, copper, and cardboard) [32].

In the second included study SARS-CoV-2 virus (final concentration ~6·8 log unit of 50% tissue culture infectious dose ($TCID_{50}$) per mL) was incubated for up to 14 days and then tested for its infectivity. The virus is highly stable at 4 °C, but sensitive to heat. At 4 °C, there was only around a 0·7 log-unit reduction of infectious titre on day 14. With the incubation temperature increased to 70 °C, the time for virus inactivation was reduced to 5 min.

Subsequently Authors investigated the stability of this virus on different surfaces. Briefly, a 5 µL droplet of virus culture (~7·8 log unit of $TCID_{50}$ per mL) was pipetted on a surface (appendix p 1; ~cm^2 per piece) and left at room temperature (22 °C) with a relative humidity of around 65%. The inoculated objects retrieved at desired time-points were immediately soaked with 200 µL of virus transport medium for 30 min to elute the virus [33].

2.2. Data Synthesis

According to the World Health Organization (WHO), the transmission of coronavirus infections, including SARS-CoV-2, occurs through droplets, droplets of diameter ≥ 5 µm that originate from the acts of breathing, speaking, coughing and sneezing. Due to their size, the droplets travel in the air for short distances, generally less than one meter, and can directly reach susceptible subjects in the immediate vicinity, as well as settling on objects or surfaces that therefore become a source of spread of the virus. In fact, in this case, hands that have come into contact with the so contaminated objects can constitute a vehicle of transmission by indirect contact when they touch the mouth, nose and eyes. Given that hand washing is always the cornerstone of correct prevention, regular cleaning followed by disinfection of surfaces and internal environments play a crucial role in preventing and containing the spread of the virus. Studies on coronaviruses, not SARS-CoV-2, such as the SARS and MERS virus, suggest that the survival time of these pathogens on surfaces, in experimental conditions, varies from a few hours to a few days depending on the material involved, concentration, temperature and humidity. It should be emphasized that this data refers to the finding of the virus RNA and not to its isolation in vital form, and therefore not related to its real infectivity [16,25,26,39–42].

2.2.1. Coronavirus on Different Surfaces

SARS-CoV-2 and SARS-CoV-1 stability in aerosols and different surfaces has been evaluated by Van Doremalen et al. [32]. They studied viruses' decay rates using Bayesian linear regression. Aerosols (<5 µm) containing SARS-CoV-2 (105.25 50% tissue-culture infectious dose (TCID50) per milliliter) or SARS-CoV-1 (106.75–7.00 TCID50 per milliliter) generated by a nebulizer have been used in their experiment. Ten different experimental conditions involving SARS-CoV-1 or 2 were evaluated. The data were expressed as 50% tissue-culture infectious dose ($TCID_{50}$) and could be seen in Table 2. The detection limit for this experiment was $3.33 \times 10^{0.5}$ $TCID_{50}$ per liter of air for

aerosols; $10^{0.5}$ $TCID_{50}$ per milliliter of medium for plastic, steel, and cardboard; and $10^{1.5}$ $TCID_{50}$ per milliliter of medium for copper. This study confirms its persistence on plastic and stainless steel which, in experimental conditions, is comparable to that of the SARS virus (SARS-CoV-1), also showing an analogue exponential decay over time. On plastics and stainless steel, the virus can resist up to 72 and 48 h, respectively, even if the infectious load on the aforementioned materials is halved after about 6 h and 7 h, respectively. The surfaces on which there is less persistence are copper and cardboard, where a complete reduction of infectivity was observed after 4 h for copper and 24 h for cardboard.

Coronaviruses' persistence on different inanimate surfaces has been analyzed by Kampf et al. [34] too. Other factors as temperature or humidity have been evaluated too. Authors showed how human coronavirus could be influenced by temperature, as 30 or 40 °C reduced the duration of persistence of coronaviruses on inanimate surfaces. However, at the temperature of 4 °C, the persistence could be greater than or equal to 28 days. A result that should be highlighed is that the persistence was longer with higher inocula. Warnes et al. [35] evaluated coronaviruses' persistence on metal and non-metal samples. Authors inoculated 10^3 plaque forming units (PFU) on different materials: polyfluorotetraethylene (Teflon; PTFE), polyvinyl chloride (PVC), ceramic tiles, glass and stainless steel. Coronaviruses' persistence was at least 5 days (and 3 days for silicon rubber) at 21 °C. Coronavirus could be rapidly inactivated by brass and nickel-plated copper surfaces in less than 60 min. Copper and nickel surfaces were effective but less than brass copper; in this case the inactivation time reached about 5 min. Warnes et al. showed how a higher percentage of copper could lead to higher antiviral properties. Another important factor reported in this study was that the release of ions from copper and the formation of reactive oxygen species (ROS) take part in the deactivation of the virus. Furthermore, the authors report that following an analysis carried out with a transmission electron microscope (TEM), the virus was normally present on surfaces such as stainless steel, often present in healthcare facilities, unlike instead of the copper surfaces that they tended to damage the virus or inactivate it. According to Van Doremalen et al. [32], aerosol and surface virus transmission is plausible, since it can remain viable and infectious for hours or days.

2.2.2. Coronaviruses in Different Temperatures and Humidity

A recent study of Chin et al. [33] assessed the stability of the SARS-CoV-2 virus at different temperatures, showing that the virus is highly stable at 4 °C, but sensitive to heat. In fact, at 4 °C there was a reduction of about 0.7 logarithmic units of the viral titre on the 14th day. By increasing the incubation temperature to 56 °C, a significant decrease in viral infectivity was observed within 10 min and, after 30 min, the virus was no longer detectable. Raising the temperature to 70 °C, the virus was no longer detectable after 5 min. The stability of the SARS-CoV-2 virus on different surfaces was also assessed in the same study. The viral titer on each surface was determined after 30 min, 3 h, 6 h, 1 day, 2 days, 4 days and 7 days of incubation, as illustrated in Tables 2–4 (Figure 1). The real novelty of this study is that persistence on some surfaces, such as the external surface of the masks, can last up to seven days [43]. Different pH seems to not statistically influence the virus persistence (Table 4). The factors influencing the persistence of microorganisms in the air/aerosol can be defined as:

- Resistance of the microorganism;
- Relative humidity of the air;
- Air temperature and sunlight;
- Aerosol composition.

Always considering that the air sampling method can affect the obtained results.

Table 3. Stability of SARS-CoV-2 at different temperatures ("/": not available data).

Time	4 °C	22 °C	37 °C	56 °C	70 °C
1 min	/	6.51 $TCID_{50}$	/	6.65 $TCID_{50}$	5.36 $TCID_{50}$
5 min	/	6.7 $TCID_{50}$	/	4.62 $TCID_{50}$	/
30 min	6.51 $TCID_{50}$	6.52 $TCID_{50}$	6.57 $TCID_{50}$	/	/
6 h	6.67 $TCID_{50}$	6.54 $TCID_{50}$	5.99 $TCID_{50}$	/	/
12 h	6.58 $TCID_{50}$	6.23 $TCID_{50}$	5.28 $TCID_{50}$	/	/
24 h	6.72 $TCID_{50}$	6.26 $TCID_{50}$	3.23 $TCID_{50}$	/	/
7 days	6.65 $TCID_{50}$	3.48 $TCID_{50}$	/	/	/
14 days	6.04 $TCID_{50}$	/	/	/	/

Table 4. Stability of SARS-CoV-2 at different pH.

pH	Log $TCID_{50}$/mL
3	5.55
4	5.67
5	5.73
6	5.75
7	5.58
8	5.70
9	5.54
10	5.51

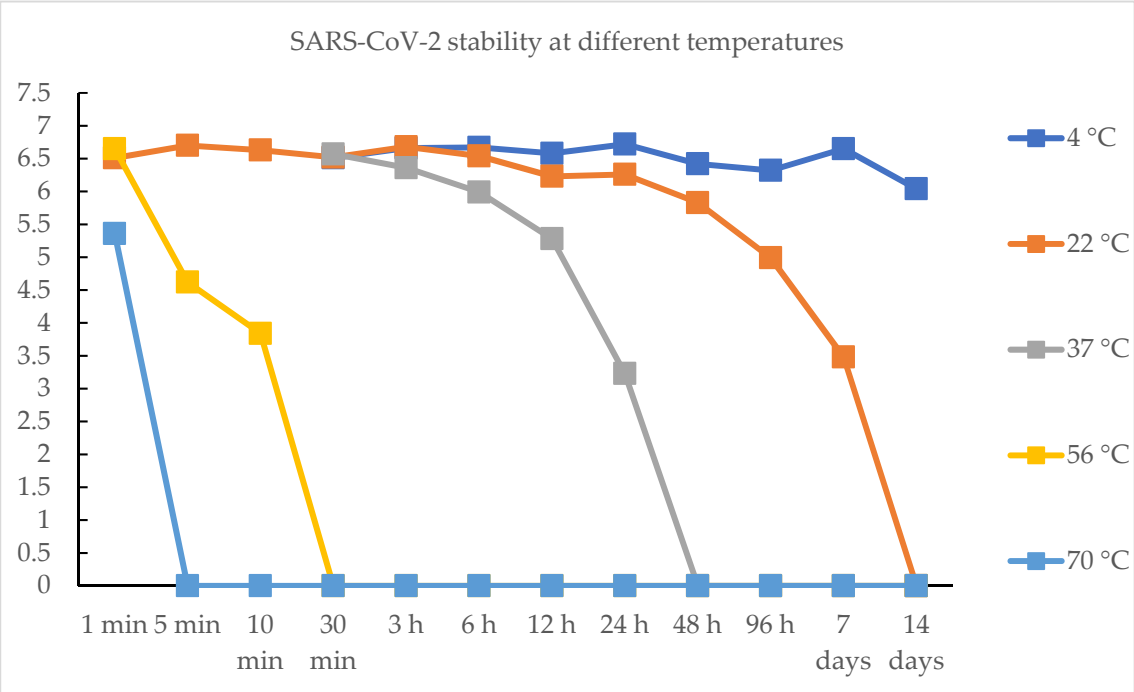

Figure 1. SARS-CoV-2 stability at different temperature over time. $TCID_{50}$ on y axis and time on x axis (0 is equal to "not detectable" virus ($\leq 10^3$ $TCID_{50}$/mL)).

2.2.3. Coronaviruses and Chemo-Physical Treatments

Furthermore, Authors evaluated the efficacy of different disinfectant on SARS-CoV-2; Household bleach, Ethanol (70%), Povidone-iodine (7.5%), Chloroxylenol (0.05%), Chlorhexidine (0.05%), Benzalkonium chloride (0.1%) obtained not detectable viruses on surfaces ($\leq 10^4$ $TCID_{50}$/mL). Treatment with chemical disinfectants of textile materials is generally not recommended, except in the case of fabrics that can be machine washed at least 60 °C with detergent and disinfectant products. In fact, some products, although suitable for their effectiveness against SARS-CoV-2, could cause degradation or swelling of the cloths and irreversible damage to the same, reducing in some cases their protective capacities. In any case, it is always a good practice to evaluate the effect of the chosen product on a hidden part of the fabric to be treated.

- Alcohols: both ethanol and propanol can interact with natural fibers causing swelling, but also their use on synthetic fibers, normally resistant to alcohol, could cause irreversible damage to colored garments, giving rise to discoloration phenomena or dissolution. In addition, the use of alcohol-based products, especially if used in a sprayed form, represents an additional risk factor related to flammability.
- Sodium hypochlorite and hydrogen peroxide: they are not recommended because they could damage colored garments causing the release of color and the formation of stains.
- Ozone: although it is capable of acting quickly on viruses, and although it has special wardrobes or boxes or other containers on the market to carry out the treatment, its use should be carefully evaluated since its oxidizing power could alter the colors of the garments and the exposure times would be a critical factor to control.
- Other chemical substances: those capable of lowering/raising the pH to denature the proteins of the viruses are strongly discouraged. In fact, natural fibers, but also some synthetic fibers, could be subject to degradation or swelling phenomena below pH 3 and above pH 10–11; moreover, the resistance, appearance, and ecotoxicological characteristics of the garment could be irreparably compromised (the major eco-toxicological specifications provide for a pH for the fabrics between 4.0 and 7.5).

Among the physical treatments, the first to be considered is heat (dry steam) for 30 min, also used according to the Koch Institute prescriptions for sanitizing surgical masks [23,44,45].

- Dry steam, in principle, is not a problem since it is already used in fabric finishing operations. The transfer of steam, as a means of contrasting the virus in a commercial context, could be practicable by the same sales staff with portable vaporizers even if the time necessary for the heat to be really effective for the complexity of the article is not standardizable, i.e., the creases, seams, turn-ups, etc., which may require a longer steaming time. It should be emphasized that any use of vaporizers should be carried out in separate rooms, to be ventilated abundantly after applying the steam in order to avoid the transfer of any contaminants from the treated fabrics to the operator by means of aerosols.
- UV radiation, in particular of the UV-C spectrum between 207–222 nm, was able to eradicate type A influenza viruses (H1N1 virus) and it can be assumed that a few minutes of application would be sufficient to also inactivate SARS-CoV-2 on clothing and clothing (both sunlight or artificial lamp). Although the use of germicidal lamps has been widespread for decades and they are already used in sanitization processes, the following critical factors for UV radiation's potential use in the textile field should be carefully considered:

  i Poor penetration; it does not penetrate paper, glass, clothing and, if the virus is nested in the fabric, it risks not being reached;
  ii Minimum distance from UV source to treated material;
  iii Energy and lamp costs (replacement every 8000 h);

iv Dependence on environmental conditions (relative humidity);
v Containment of operator exposure considering mutagenicity for humans (skin, eyes): in this case the 222 nm radiation, the most active on viruses, is the least penetrating in the skin and dangerous for humans but the eyes should still be protected;
vi Degradation of colors, especially for less solid shades, since every minute of exposure to light ultraviolet of the lamp corresponds to a few hours of exposure to sunlight [46–51].

Ultraviolet (UV) light is electromagnetic radiation with wavelengths shorter than those of light. UV can be divided into various categories, the short category (UVC) is considered "germicidal UV". At certain wavelengths, UV is harmful to bacteria, viruses and other microorganisms. At a wavelength of 2537 Angstrom (254 nm) UV destroys the molecular bonds in the DNA of microorganisms, producing thymine dimers in their DNA and destroying them, rendering them harmless or preventing their growth and reproduction. It is a process similar to the effect of longer wavelength UV (UVB) on humans, for example sunburn or the blinding effect of light. Microorganisms have poor UV protection and cannot survive prolonged exposure. UVGI (Ultraviolet germicidal irradiation) can be used to disinfect the air with prolonged exposure [52,53]. Disinfection depends on the UV concentration and the exposure time. For this reason, it is not effective on moving air, when the lamp is perpendicular to the flow, as exposure times are drastically reduced [54].

A different disinfection method should be considered for each different material as showed in Table 5.

Table 5. Disinfection methods of different surfaces or materials.

Type of Surface or Material	Detergent/Disinfectant
Surfaces in stone, metal, or glass except wood	Neutral detergent and disinfectant virucidal—sodium hypochlorite 0.1% or ethanol (ethyl alcohol) at 70% or other concentration, provided that virucidal is specified
Wooden surfaces	Neutral detergent and virucidal disinfectant (against viruses) based on ethanol (70%) or quaternary ammoniums (e.g., benzalkonium chloride; DDAC (Didecyldimethylammonium chloride))
Toilets	Cleaning with detergent and disinfection with disinfectant based on sodium hypochlorite at least 0.1% sodium hypochlorite
Textiles (e.g., cotton, linen)	Washing with hot water (70 °C–90 °C) and normal laundry detergent; alternatively: low temperature washing with bleach or other disinfectants for laundry.

As can be seen from this manuscript, some common surfaces, such as cardboard, show a shorter persistence time of the virus. Compared to what one might think, therefore, an absorbent surface tends to decrease the persistence time compared to plastic. The virucidal action of copper seems to give promising results, but there are no differences between surfaces for common use compared to those for sanitary use.

3. Methods

PRISMA statement has been followed [55–58] to conduct the source of this data summary; PRISMA is an evidence-based minimum set of items for reporting. PRISMA focuses on the reporting of reviews evaluating randomized trials, but can also be used as a basis for reporting systematic reviews of other types of research, particularly evaluations of interventions. PRISMA aims to help authors improve the reporting of systematic reviews and meta-analyses. PRISMA may also be useful for the critical appraisal of published manuscripts. Eligibility criteria have been stated as follows:

- SARS-CoV-2 features articles;
- SARS-CoV-2 persistence;

- The persistence of other coronaviruses.

The following were the exclusion criteria:

- Not enough information regarding the topic;
- No access to the title and abstract.

Research was conducted in four electronic databases: PubMed, EMBASE, Elsevier, and MDPI. In addition, a manual search was conducted for relevant studies published. Digital and manual searches were then performed. The data search was performed in order to add significant studies and to increase the sensitivity of this study.

During the first search, 26 studies were obtained. After applying inclusion and exclusion criteria, only the remaining six articles were further analyzed. Then, articles were manually selected, and finally five articles were obtained (Figure 2). Information sources often tend to generate results that are not inherent or that do not contain any information about the requested topic. The excluded results were read by the authors and only after a collective analysis were eliminated and reported as having "not enough information about the topic".

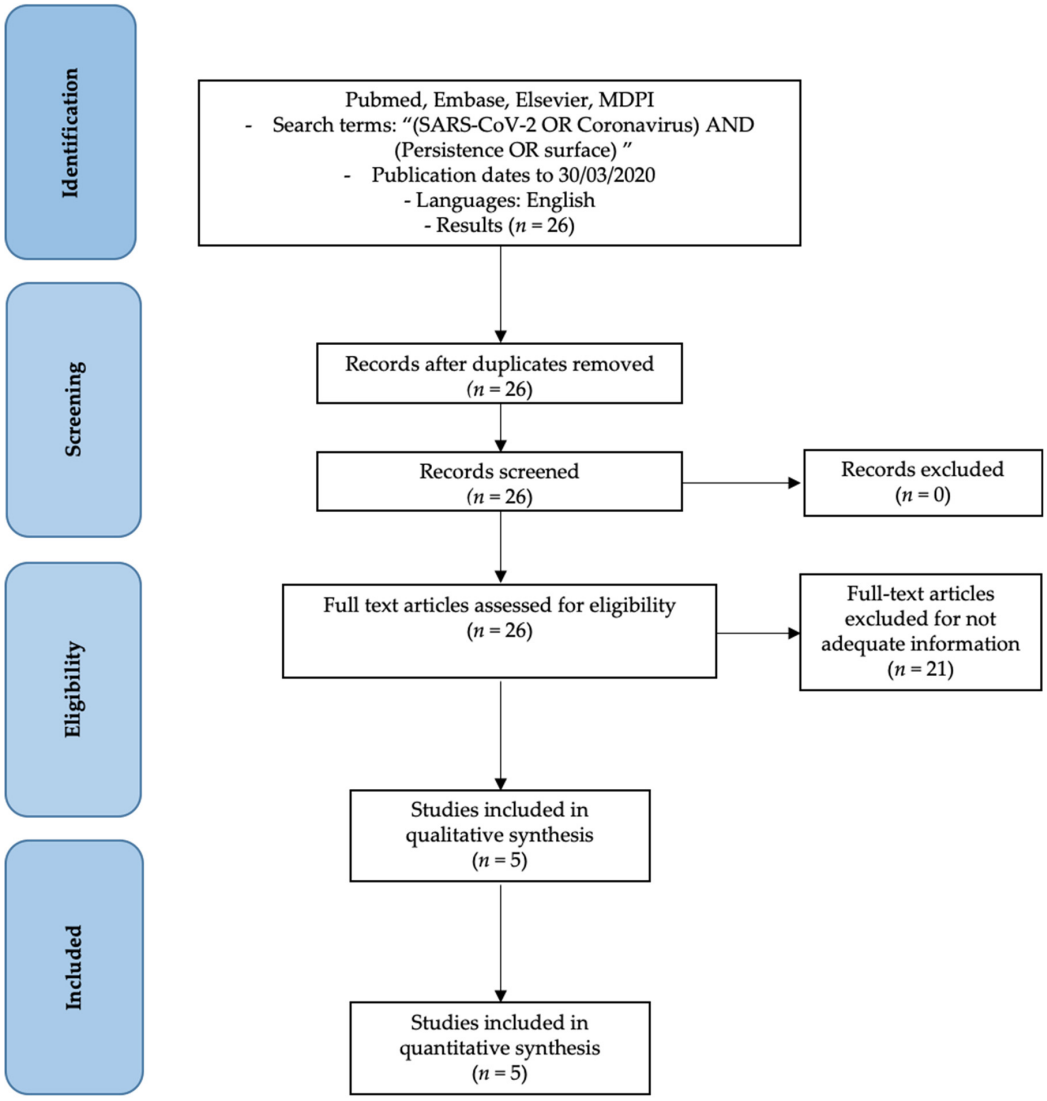

Figure 2. PRISMA checklist. This is a flowchart that graphically describes the sequence of steps defined for the exclusion of the studies under consideration. The rationale behind including such a diagram is to increase the transparency of decisions made by the researcher to include or exclude certain studies, which may subsequently introduce bias to the overall extent of the effect.

4. Conclusions

The purpose of this study is to clarify what the characteristics or the persistence times of the new Coronavirus are. In particular, attention has been focused, as well as on the times, also on the necessary conditions (such as humidity or temperature), and on the type of surface. Surely these data will be useful for drawing up new guidelines and for clarifying some protocols. Other studies are needed to evaluate the persistence of coronavirus on different surfaces or in aerosols. It currently appears that the persistence of the virus is favored by a low temperature (4 °C) and is gradually inactivated by the increase of the latter. Furthermore, could be said how the pH weakly influence this persistence unlike the type of surface, in fact plastic has the longest persistence times of the virus in active form instead of surfaces with active properties against the virus such as copper, where it is inactivated in a few hours. Having these results regarding temperature, humidity and surface material is useful for setting guidelines for prevention. Certainly, other studies would be useful, and should further clarify the resistance to climatic conditions of this virus. It would be useful to understand if the conditions of pollution or particulate matter in the air can favor the persistence of the virus in the aerosol, and also to evaluate the effectiveness of the sun's rays. It would also be interesting to know if the virus has different persistence times on human skin, or if some virucidal activity is carried out against it.

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