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Review article

Mohamed A. Deyab*

Coronaviruses widespread on nonliving surfaces: important questions and promising answers

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Abstract: The world is facing, while writing this review, a global pandemic due to one of the types of the coronaviruses (i.e., COVID-19), which is a new virus. Among the most important reasons for the transmission of infection between humans is the presence of this virus active on the surfaces and materials. Here, we addressed important questions such as do coronaviruses remain active on the inanimate surfaces? Do the types of inanimate surfaces affect the activity of coronaviruses? What are the most suitable ingredients that used to inactivate viruses? This review article addressed many of the works that were done in the previous periods on the survival of many viruses from the coronaviruses family on various surfaces such as steel, glass, plastic, Teflon, ceramic tiles, silicon rubber and stainless steel copper alloys, Al surface, sterile sponges, surgical gloves and sterile latex. The impacts of environmental conditions such as temperature and humidity were presented and discussed. The most important active ingredients that can deactivate viruses on the surfaces were reported here. We hope that these active ingredients will have the same effect on COVID-19.

Keywords: coronaviruses; COVID-19; disinfectants; persistence; surfaces; virucidal activity.

1 Introduction

Viruses are defined as an infective agent needs living cells to generate more viruses [1]. Viruses have an independent fragment shape. They contain two parts. The first part is called genetic part. This part represents the deoxyribonucleic acid (DNA) for the virus. The second part represents the protein layer [2]. This protein layer can protect the virus from outside. Generally, viruses have three main shapes i.e., helical and icosahedral and complex structures [3] (see Figure 1).

The strategy of virus to infect the human depends on different ways. One way based on vectors, where these vectors such as insects can transmit viruses from man to man [4]. Some viruses such as human immunodeficiency viruses (HIV) can be carried through sexual relations [5]. The most dangerous way for infecting the human by viruses can result from coughing, sneezing, and contact with the surfaces by hands or oral route [6].

One of the most dangerous types of viruses that use this way is coronaviruses which cause respiratory tract infections for humans [7–10].

Coronaviruses family including SARS-CoV (discovered in 2003), HCoV NL63 (discovered in 2004), HKU1 (discovered in 2005), MERS-CoV (discovered in 2012), and SARS-CoV-2 (2019-nCoV) (discovered in 2019) [11–14]. SARS-CoV caused infection for more than 8000 persons and ended the life of more than 774 people [15]. This infection carried out by direct and indirect contact with surface and materials containing SARS-CoV. In this review, we will address the remaining of coronaviruses on the different types of surface and materials. In addition, what are the most suitable ingredients that used to inactivate viruses?

2 The permanence of coronaviruses on the surfaces

The most important question arises here; do the coronaviruses remain active on different surfaces? What are the time periods for the virus to remain active? Is the duration of the active virus varies according to the type of surface? All of these questions were answered by many of the researches that have been done recently and we will list the details in this part.

In 2013, Doremalen et al. [16] studied the influence of MERS-CoV and A/Mexico/4108/2009 (H1N1) virus on the plastic and steel materials at different temperature (T) and relative humidity (RH%). They found that the plastic and

***Corresponding author: Mohamed A. Deyab**, Egyptian Petroleum Research Institute (EPRI), PO Box 11727, Nasr City, Cairo, Egypt, E-mail: hamadadeiab@yahoo.com

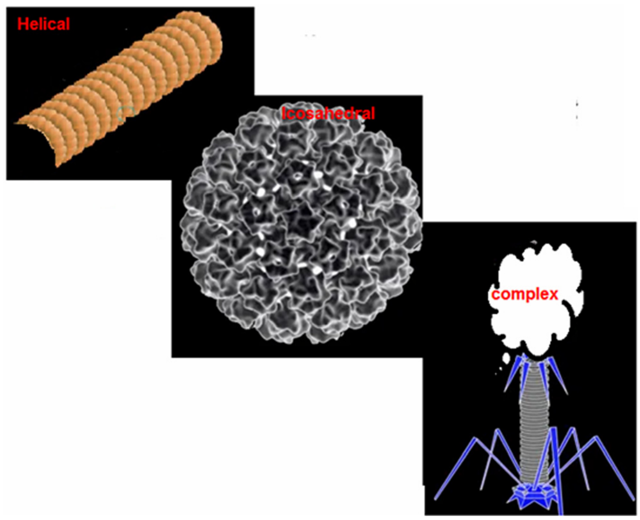

Figure 1: The main shapes of viruses.

steel materials did not affect the stability of the presence of both viruses on their surfaces. They indicated that MERS-CoV is more active on the surfaces of plastic and steel materials than A/Mexico/4108/2009 (H1N1) virus. In the case of MERS-CoV, at condition T = 20 °C and RH% = 40%, MERS-CoV virus was active after 48 h and no active virus was noted after 72 h. At condition T = 30 °C and RH% = 30%, MERS-CoV virus was active after 24 h and no active virus was noted after 48 h. At condition T = 30 °C and RH% = 80%, MERS-CoV virus was active after 8 h and no active virus was noted after 24 h. In the case of A/Mexico/4108/2009 (H1N1) virus, at each condition no active virus was noted after 4 h. where the changes in conditions do not affect on the virus activity. This means that the activity of MERS-CoV depends on the environmental conditions, where this virus remains viable for a long time at low temperatures and low humidity.

Casanova et al. [17] focused on the study of the effect of environmental conditions such as temperature and relative humidity on the remaining viable of coronavirus on stainless steel surface. In this work they used two probable surrogates such as transmissible gastroenteritis virus (TGEV) and mouse hepatitis virus (MHV). At very low temperature (4 °C) the TGEV and MHV remain active for 28 days. The 20% RH resulted in the minimum grade of inactivation. They found that by increasing the temperature from 4 to 20 °C, the inactivation of both viruses increased at all percentages of RH. They indicated that at 50% RH, TGEV and MHV remain active (at titers of 4 to 5 $\log_{10}$ most probable numbers MPN) for three days. In this case, the mathematical meaning of log10 is the viral load values as a power of ten (written log10). By decreasing the RH to 20% the virus persisted for 28 days. The best inactivation was obtained at humidity 50%. In this condition, TGEV and MHV proportion came down to 2 log10 and 3 log10 on the third and fifth days, respectively. The raising of temperature from 20 to 40 °C has a great effect on the activity of both viruses. Where both viruses persisted for 5 days at 20% RH. The change in RH from 20 to 40% to 80% reduces the time that viruses remain active in the range 24–6 h.

The explanation of these results depends on two facts. The first fact states that the virus architecture structure may be damaged due to the accumulation of virus capsids at the air-H_2O interface [18]. The second fact sates that the dryness of the surface may affect the lipid membrane and Maillard reaction causing virus's inactivation [19]. At a low humidity environment (Around 20%), the second fact is the predominant factor. However, at a high humidity environment (Around 80%), the first fact is the predominant factor [20]. At intermediate humidity environment (Around 50%), the two mechanisms work in the same time and this leads to the best condition for viral inactivation.

By considering the wide range of materials, Warnes et al. [21] indicated that coronavirus remains active on the surface of the glass, Teflon, ceramic tiles, silicon rubber and stainless steel form 3 to 5 days at 21 °C and RH of 30 to 40%.

It is interesting to see the effectiveness of the copper alloys in deactivating viruses that are deposited on their surfaces. This data were detected Warnes et al. [21]. They found that copper alloys can inactivate coronavirus 229E within a few minutes. Generally brass alloy is the generic name for a range of Cu/Zn alloys. It was found that the Cu/Zn alloy contains 70% Cu was the best efficient alloy in the field. This means that there is a direct relation between the rate of virus inactivation and Cu percentage in the brasses alloy. Cu/Ni alloys have the same efficient influences on the rate of virus inactivation but it needs higher Cu% (90%) comparing with brasses (70%).

Warnes and Keevil [22] pointed to the responsibility of Cu ions on the inactivating norovirus. In the same direction, Warnes et al. [21] indicated that Cu^{+} and Cu^{2+} ions are also necessary for coronaviruses inactivation. Similar results were detected by Karlstrom et al. [23] and Sagripanti [24]. They indicated that Cu ions are able to block viral proteases through the reaction with cysteine causing deterioration in the viral genome. Accordingly, we recommend the use of brass alloy to construct the public and clinic areas to minimize the activity of viruses.

It is very important to see the activity of coronaviruses in the hospital environment. In this regard, Sizun et al. [25] investigated the activities of two types of coronaviruses (i.e., HCoV-229E and HCoV-OC43) on the Al surface, sterile sponges, surgical gloves and sterile latex. They found that coronaviruses are able to remain active for a few days (from 3 to 5 days) in wet cases and for a few hours (3 h) after dry cases. Therefore, all precautions must be taken to eliminate all types of viruses from the surfaces in the hospital environment to reduce person-to-person infections.

SARS coronavirus survive in different human conditions was clearly discussed by Duan et al. [26]. They found that this virus remains active in serum and urine for 96 and 72 h, respectively. The activity of viruses depends on the surrounding temperature, where they remain active at temperature range 4–37 °C for at least 2 h. The SARS coronavirus becomes inactive at high temperatures (i.e., 56, 67, and 75 °C). They indicated also the use of UV for at least 60 min led to virus inactivation with a high degree.

3 The active ingredients to deactivate coronaviruses viruses

In this part, we will discuss the most important research works that contain the most active ingredients (AI) that are used in the elimination of viruses to ensure prevent the transmission of infection between humans.

In 2009, Dellanno et al. [27] investigated the ability of some common household disinfectants and antiseptics products to deactivate MHV as a potential surrogate for SARS-CoV. They found that the use of Dettol (AI = 0.21% Chloroxylenol, Its systematic IUPAC name is 4-Chloro-3,5-dimethylphenol), Lyso (AI = 0.1% Alkyl dimethyl benzyl ammonium), Clorox (AI = 0.21% Sodium hypochlorite), antibacterial soap (AI = 0.05% Triclosan, its systematic IUPAC name is 5-chloro-2-(2,4-dichlorophenoxy)phenol), and Pine-Sol (AI = 0.23% Pine oil) are able to eliminate the virus in 30 s (see Figure 2).

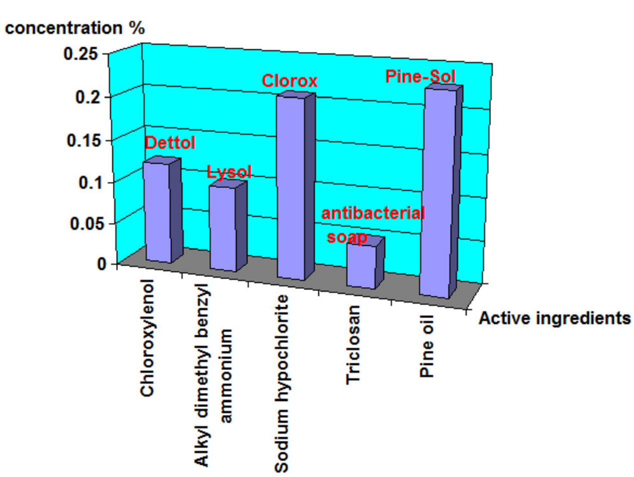

Figure 2: Common household disinfectants and antiseptics products and their concentrations.

Rabenau et al. [28] presented a comprehensive study on the effect of some commercial eight disinfectants on the activity of SARS-CoV. The types of application of these disinfectants are hand rub (four products), surface disinfectant (three products) and instrument disinfectant (one product). The active ingredients for these products can be summarized as the following:

i. Sterilliu hand rub (hand rub): 45% iso-propanol, 30% n-propanol and 0.2% mecetronium etilsulphate.
ii. Sterillium Rub (hand rub): 80% ethanol.
iii. Sterillium Gel (hand rub): 85% ethanol.
iv. Sterillium Virugard (hand rub): 95% ethanol.
v. Mikrobac forte (surface disinfectant): benzalkonium chloride and laurylamine.
vi. Korsolin FF (surface disinfectant): benzalkonium chloride, glutaraldehyde and didecyldimonium chloride
vii. Dismozon pur (surface disinfectant): magnesium monoperphthalate.
viii. Korsolex basic (instrument disinfectant): glutaraldehyde and (ethylenedioxy) dimethanol.

They indicated that all the hand rub products are able to deactivate SARS-CoV within 30 s. The surface disinfectant products cause a very low decrease in the virus presence within 30 min. The instrument disinfectant product can eliminate the SARS-CoV in the short time depending on the concentration of active ingredient (i.e., 60 min [AI = 2%], 30 min [AI = 3%], and 15 min [AI = 4%]).

Recently, Kampf [29] presented some recommendations on the use of some active ingredients that used to disinfect the surface to prevent coronavirus infectivity. He mentioned that there are some active ingredients with an effective concentration (EC %) can disinfectant the surface in 1 min such as C_2H_5OH (EC% = 62–71%), H_2O_2 (EC% = 0.5%), and NaOCl (EC% = 0.1%).

Wood and Payne [30] investigated the effect of chloroxylenol, benzalkonium chloride and cetrimide/chlorhexidine on the activity of enveloped and non-enveloped human viruses. They indicated all these ingredients can inactivate the herpes simplex virus (HSV) and HIV within 1.0 min. They found that the benzalkonium chloride has a good role in inactivating the non-enveloped human coxsackie virus. The main mechanism for the role of benzalkonium chloride depends on the ability of this compound on the alterations of the components for sites that interact with a receptor on the host cell. Similar behavior was noticed by Grossgebauer [31].

The efficiency of povidone iodine as against coronavirus was investigated by Eggers et al. [32]. They indicated the povidone iodine with different concentrations is able to inactivation of MERS-CoV within sec. the efficiency of povidone iodine reaches to 99.99%. They mentioned that povidone iodine is more effective than sanitizers based on ethanol in inactivating murine norovirus. In addition, povidone iodine can effectively affect on a broad range of enveloped and non-enveloped viruses. Kariwa et al. [33] indicated that povidone iodine can also inactivate SARS coronavirus within 2 min. This means that the povidone iodine can be used instead of ethanol in hand gel, hospitals and households products to inactive the coronavirus. Povidone iodine attacks the structures of coronavirus and prevents the replication of microorganisms. In this case, the iodine molecules can oxidize vital pathogen structures such as amino acids, nucleic acids and membrane components.

The aldehydes and butylated hydroxytoluene (BHT) compounds are considered as an efficiency agent to inactivation viruses. This clearly was discussed by Pratelli [34]. They indicated that the glutaraldehyde and formaldehyde can successfully inactivate the virus. Aldehydes action depends on their interaction with proteins and DNA of viruses. They found that the efficiency of aldehydes depends on temperature, concentration and contact time.

In the same direction, BHT can effectively affects on pseudorabies virus (PRV) in cell culture, mice, and swine [35]. Its antioxidant properties are used to inhibit the free radical-mediated oxidation in fluids [36, 37]. By adding small doses of BHT at 37 °C for 60 min, the cell cultures did not become infected with virus.

4 Conclusions

(1) Coronaviruses cause respiratory tract infections for humans by direct and indirect contact with surface and materials.
(2) Coronaviruse remains active on surface and materials for up few days.
(3) The environmental conditions such as temperature and relative humidity have a great effect on the persistence of coronaviruses on surfaces.
(4) The best conditions for coronaviruses inactivation were obtained at humidity 50% and at high temperature (>40 °C).
(5) Copper alloy was used to construct the public and clinic areas to minimize the activity of viruses.
(6) The most active ingredients that are used in the elimination of coronaviruses include chloroxylenol, alkyl dimethyl benzyl ammonium, sodium hypochlorite, triclosan, pine oil, iso-propanol, n-propanol, mecetronium etilsulphate, benzalkonium chloride, laurylamine, glutaraldehyde, didecyldimonium chloride, magnesium monoperphthalate, ethylenedioxy, hydrogen peroxide, povidone iodine, and aldehydes compounds.
(7) We look forward to obtaining a similar effect against the COVID-19.

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