

REVIEW

Using heat to kill SARS-CoV-2

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Email: jpabraham@stthomas.edu**Summary**

The current coronavirus pandemic has reached global proportions and requires unparalleled collective and individual efforts to slow its spread. One critically important issue is the proper sterilization of physical objects that have been contaminated by the virus. Here, we review the currently existing literature on thermal inactivation of coronavirus (SARS-CoV-2) and present preliminary guideless on temperatures and exposure durations required to sterilize. We also compare these temperatures/exposure durations with potential household appliances that may be thought capable of performing sterilization.

1 | INTRODUCTION

As societies put themselves into voluntary or enforced isolation, large populations of people are experiencing reduced contact with others in public. When people venture into public, they are often donning masks (homemade or industrially produced) or other protective clothing. Upon returning to isolation, masks and other clothing should be treated as contaminated with virus.

How should masks, clothing, and other items be treated? In many instances, simply setting items aside for a long enough period of time will kill the virus. However, the required durations are not known absolutely, and certainly depend on the type of surface.¹⁻⁵ Some clothing types, for instance, are very capable of retaining moisture and consequently, this affects the survival of virus contained therein. The general consensus is that viruses can survive up to a few days in clothing. It is reasonable to expect a similar survival duration for viruses on/in protective face masks. That is, contaminated masks can be treated by merely setting them aside for some required duration until the viruses die. But to our best knowledge, there is no scientific study on the required duration, and any required duration would depend on the materials that form the mask. For instance, woven fibers differ from non-woven polymeric filter media. Mask users can apply sanitizing chemicals (such as alcohol) but it is not clear whether this type of sanitizing would adversely affect the porous structure of masks and thereby make them less effective over time. Similarly, there is no current advice available for the use of heat to destroy SARS-CoV-2.

Here, we summarize all the existing temperature/duration information for both SARS-CoV-2 and its sensitivity to heat. The summary

is used to provide a reasonable recommendation for users to thermally destroy viruses on masks, clothing, or other objects.

1.1 | Summary of the existing literature

An example of the state of knowledge on temperatures and coronavirus survival is provided by the CDC, which states:

"Generally coronaviruses survive for shorter periods at higher temperatures and higher humidity than in cooler or dryer environments. However, we don't have direct data for this virus, nor do we have direct data for a temperature-based cutoff for inactivation at this point. The necessary temperature would also be based on the materials of the surface, the environment, etc."⁶

But despite official statements such as the above, there is, in fact, some literature on the temperature and exposure durations that are required to inactivate SARS-CoV-2. In the following, a list of temperature/duration/inactivation rates is provided for coronavirus pathogens. In the listing, we report log reductions in viral load obtained from the references. In some studies, the heating protocol was such that no viral presence was detected afterwards. We have substituted an equivalent log reduction of 7 for these cases. Of course, the actual log reduction would be based on the sensitivity of the measurement instruments; however, for practical purposes, we consider a viral reduction of 7 or greater to be at or near total sterilization.

In Table 1, we present this literature information. We note that there are differences in the strains and media in which the virus was cultivated. We also acknowledge that there are different thermal sensitivities for differing strains. It is further known that the media can

TABLE 1 List of exposure temperatures and durations for inactivating coronavirus strains

Temperature (°C, °F)	Duration (minutes)	Log reduction	Virus	References
56, 133	10	5	SARS-CoV (Urbani strain)	9
56, 133	20	6	SARS-CoV (Urbani strain)	9
65, 149	3	6	SARS-CoV (Urbani strain)	9
75, 167	15	7	SARS-CoV (Urbani strain)	9
55, 131	120	5	Gastroenteritis coronavirus	10
56, 133	60	7	Canine coronavirus	11
65, 149	40	7	Canine coronavirus	11
75, 167	15	7	Canine coronavirus	11
56, 133	50	5	Canine coronavirus	11
65, 149	5	5	Canine coronavirus	11
75, 167	4	5	Canine coronavirus	11
56, 133	30	>5	SARS CoV, FFM1 no protein	12
50, 122	30	1.9	SARS, CoV, FFM1 With 20% protein	12
60, 140	30	>5	SARS CoV, FFM1 no protein	12
60, 140	30	>5	SARS, CoV, FFM1 With 20% protein	12
56, 133	5	5.8	SARS CoV (Hanoi strain)	13
56, 133	10	6.5	SARS CoV (Hanoi strain)	13
56, 133	30	>6.4	SARS CoV (Hanoi strain)	13
56, 133	30	2–5	SARS CoV (FFM1 strain)	13
56, 133	20	>4.3	SARS CoV (Urbani strain)	13
60, 140	30	>5	SARS CoV (FFM1 strain)	13
60, 140	30	>4	SARS CoV (FFM1 strain)	13
60, 140	60	>4	SARS CoV (FFM1 strain)	13
65, 149	10	>4.3	SARS CoV (Urbani strain)	13

affect the viral survival. For instance, media with protein content make the virus more resistant to heating. With this acknowledged, we opt to not provide separate analysis for different strains or media. Rather, our intent is to provide a single thermal recommendation that can be used to sterilize a broad range of materials.

What is seen from these tabulations is that the independent studies are mutually reinforcing. The results from Table 1 can be used to formulate general guidelines for the public.

1.2 | Recommendations for thermally destroying coronavirus

We provide a reasonable estimate for near complete thermal destruction of coronavirus. For temperatures above 65°C (149°F) is expected to cause near complete inactivation with exposures greater than 3 minutes. For temperatures between 55 and 60°C (131–140°F) heating should last 5 minutes or more. However, for temperatures in the range 50–55°C (122–131°F) we recommend 20 minutes or longer of exposure. At these levels, we expect the viral concentration to be lowered by log 5–7, near or below the detectable limit.

Because of the seriousness of the current coronavirus infection, we suggest a reasonable safety factor can be obtained by increasing

the above-listed temperatures by 10°C (about 18°F). Extensive research has confirmed that at least for living cells, the sensitivity of thermal destruction is very strongly linked to temperature. That is, small increases in temperature cause large increases in the death rate. As an example, for mammalian cells and other pathogens (bacteria, viruses, and protozoa) the death rate rises rapidly as temperature increases.^{7,8} Another reason for using a safety factor is that the temperatures experienced by the virus during heating will not necessarily equal the temperature of the applied heat. Thermal inertia causes a heating lag that depends, in part, on the media being heated.

With this conservative approach, the following become the recommendations:

In order to kill COVID-19, heat virus-containing objects for:

- 3 minutes at temperature above 75°C (160°F).
- 5 minutes for temperatures above 65°C (149°F).
- 20 minutes for temperatures above 60°C (140°F).

It should be noted that these findings agree with WHO guidelines which report a 4 log reduction of coronavirus for 56°C (133°F) with 15-minute exposures¹⁴ and is consistent with information for killing other infectious agents.¹⁵

These recommendations are hotter than encountered in residential clothes dryers, clothes washing machines, and dish washers. For these appliances, temperatures are typically at or below 57°C (135°F). These temperatures are also much hotter than residential hot water (in the United States), for example, plumbing codes limit hot water to 49°C (120°F).

Of course, since soap has some virucide characteristics, washing with soap is expected to inactivate viruses by nonthermal means.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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