REALM Preliminary Literature Review Now Available

The REopening Archives, Libraries, and Museums (REALM) Project is conducting literature reviews to help define the scope of the project's research and the information needs of libraries, archives, and museums. The first review has been completed by researchers at Battelle; this document offers a set of findings from publicly available scientific literature. This information helps to set the context for the laboratory research that is being conducted during the REALM Project. This preliminary review focused on studies of virus attenuation on commonly found materials, such as paper, plastic, cloth, and metal; methods of virus transmission; and effectiveness of prevention and decontamination measures. A fuller, more systematic literature review is also in progress and will be released later in June.

As you read this preliminary literature review, keep in mind a few key points:

1. The research and information captured in the findings include both peer-reviewed and non-peer-reviewed studies. In the interest to publish emerging research related to the COVID-19 pandemic as quickly as possible, publication has been expedited rather than waiting for time intensive peer review.

2. The studies included in the review have been conducted by different researchers, under different conditions, likely using different concentrations —and possibly sources—of the virus. This makes it difficult, if not impossible, for a reviewer to make a straight comparison across studies; and, interpreting the results may be challenging for readers without a science background. The systematic review which will follow this preliminary review will include a synthesis and more analysis to help with the interpretation; that review will be released later in June.

3. The review includes findings for industries, such as health care, that operate under considerably different constraints and risk factors than do libraries, archives, and museums, (abbreviated LAMs). However, in this preliminary search, it was important to consider a broad range of available research to determine what may be applicable to LAM operations and identify what research gaps exist. The research captured in the review does not represent recommendations or guidance for LAMs; but, commonalities with other fields and industries may be found as the research proceeds, and the project will continue to monitor the science literature for emerging science-based information that relates to LAM operations.

The project team will continue to collect and review published literature related to COVID-19 and share out those findings with the LAM community.

Preliminary Literature Review for the Natural Attenuation of SARS-CoV-2 as a Decontamination Approach

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This document was sponsored by and prepared under auspices of Battelle Contract Number: CON00031948

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1. Introduction

1.1. Purpose of Literature Review

Battelle is conducting a literature review to gather and evaluate existing research about SARS-CoV-2 (the virus that causes COVID-19) related to the following research questions:

1. How does the virus spread through public library general operations?
2. How long does the virus survive on material surfaces through environmental attenuation?
3. How effective are various prevention and decontamination measures that are readily available to public libraries in the near term?

2. Methods

Battelle is conducting a systematic literature review, but first Battelle performed an organic, targeted search of the research landscape as an exploratory preliminary step. Battelle research staff searched research tools such as PubMed, WorldCat Discovery, and Google Scholar to identify scholarly articles that address the novel coronavirus SARS-CoV-2 in terms of the research questions above. As such, emphasis was given to peer-reviewed articles that directly discussed SARS-CoV-2 in terms of its survivability on surfaces, effective prevention and decontamination measures, and how the virus may spread through library operations (especially aerosol transmission). However, due to the emerging nature of the research topic and the amount of time typically required for publication of rigorous scientific studies, in many cases relevant articles found are those that have been published online in "pre-print," "letter to the editor," "early release," or other sub-optimal forms. In these cases, the articles have not undergone the traditional scholarly peer review needed to vet the scientific quality of research methods and findings, so the findings from these articles must be approached with considerable caution where present.

3. Findings

The findings of the preliminary search are presented below, organized by research question.

3.1. Spread of SARS-CoV-2 through public library operations

Two primary types of transmission available in the literature search were aerosol transmission and the transmission of SARS-CoV-2 near people who have been infected with the virus.

3.1.1. Aerosol Transmission

In "Master Question List for COVID-19 (caused by SARS-CoV-2)," a literature review published by Department of Homeland Security Science and Technology Directorate, it was concluded that, "If aerosolized intentionally, SARS-CoV-2 is stable for at least several hours" (p. 12).

In another study, airborne transmission was found to be minimal, though this may have been due to a small sample size or the specific air filtration system in place. Cheng et al. (2020) reported that, in an “airborne infection isolation room” in a Hong Kong hospital, an experienced infection control nurse collected air samples 10 cm from the mouth of a patient diagnosed as infected with SARS-CoV-2 as the patient engaged in four types of respiratory activities: breathe normally, breathe deeply, speak continuously, and cough continuously, while putting on and taking off a surgical mask. The patient's nose/throat swabs were said to have a "moderate" viral load of 3.3 $\times 10^6$ copies per mL and the saliva was 5.9 $\times 10^6$ copies per mL. The air samples were undetectable for SARS-CoV-2 RNA. The authors said they could not make a definitive conclusion based on having one patient sample, but they attributed the lack of detectable virus in the eight air samples to the use of air cleaning in the isolation rooms (12 air changes/hour) or to limited airborne transmission of SARS-CoV-2.

In an early release article (i.e., not considered final until publication in July 2020), Guo et al. (2020) presented results from air sampling in an intensive care unit (ICU) and a general COVID-19 ward to evaluate the distribution of and potential exposure to SARS-CoV-2 in full or near capacity hospitals. The authors collected indoor air samples from sites in close proximity to 15 ICU patients and 24 general ward patients. SARS-CoV-2 was found to be widely distributed in the air in both the ICU and general ward. The authors concluded that "SARS-CoV-2 aerosol distribution characteristics in the [general ward] indicate that the transmission distance of SARS-CoV-2 might be 4 m" (n.p.). The authors noted two limitations with the study. Firstly, the results of a nucleic acid test did not indicate the amount of viable virus. Secondly, the authors noted that "the aerosol transmission distance cannot be strictly determined" for a minimal infectious dose (n.p.).

Ferioli, Cisternino, Leo, Pisani, Palange, and Nava (2020) conducted a literature review to assess findings related to SARS-CoV-2 transmission risk for healthcare workers in contact with patients undergoing respiratory therapies, safety measures to minimize transmission from contact with exhaled droplets, and suggested precautions that can minimize aerosol-based transmission of SARS-CoV-2 in patients with COVID-19. They reported that coughing without a mask can be expelled 68 cm, though this is reduced to 30 cm if a mask is worn and to 15 cm if the mask is an N95; however, side leakage was not accounted for. SARS-CoV-2 transmission has been found to be conducted through droplets, which can be exhaled up to 1 meter from the source, depending on force and environmental conditions, and only suspend in the air for a short time.

In a letter to the editor, van Doremalen and colleagues (2020) examined the stability of SARS-CoV-2 in aerosols (and on different surfaces). “Aerosols(<5 μm) containing SARS-CoV-2 ($10^{5.25}$ 50% tissue-culture infectious dose [$TCID_{50}$] per milliliter) or SARS-CoV-1 ($10^{6.75\text{-}7.00}$ $TCID_{50}$ per milliliter) 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” (p.1). Results showed that SARS-CoV-2 was viable in aerosols after three hours. The virus titer reduced from $10^{3.5}$ to $10^{2.7}$ $TCID_{50}$ per liter of air which was similar to the reduction observed with SARS-CoV-1 (from $10^{4.3}$ to $10^{3.5}$ $TCID_{50}$ per milliliter. The median half-lives of 1.1 to 1.2 hours were similar for SARS-CoV-2 (95% credible intervals of 0.64 to 2.64) and SAR-CoV-1 (0.78 to 2.43). These findings indicate that the aerosol transmission of SARS-CoV-2 is plausible.

Faridi and colleagues (2020) examined air samples from the rooms of patients experiencing severe and critical SARS-CoV-2 symptoms in a hospital in Tehran, Iran. The impinger technique was used to collect air samples from 1.5 to 1.8 m from the floor and at least 2 to 5 m away from patients' beds then these samples were transferred to a laboratory of the detection of SARS-CoV-2. The indoor CO_2 concentration, relative humidity and temperature in the rooms were also recorded. Findings of the study indicated that the SARS-CoV-2 was not detected of in any of the air samples collected. Based on the inconsistent findings around the aerosol transmission of SARS-CoV-2, the authors suggested that in vivo experiments that utilize actual cough, sneeze, and breath samples of people who have tested positive for the virus are needed.

3.1.2. Other Routes of Transmission

Surfaces near infected persons

Cheng et al. (2020) also conducted an environmental pilot experiment in a Hong Kong hospital testing transmission of SARS-CoV-2 within the "airborne infection isolation room" of an infected patient. The patient was said to have a "moderate" viral load of 3.3 $\times 10^6$ copies per mL and the saliva was 5.9 $\times 10^6$ copies per mL. In the environmental experiment, an experienced infection control nurse collected air samples 10 cm from the patient's mouth while the patient breathed, spoke, and coughed. The researchers collected specimens from the room (bench, bed railing, locker, bed table, alcohol dispenser, and window bench; exact surface types were not named) before and after the air samples were conducted to assess distribution of the virus by air. No samples were undetectable for SARS-CoV-2 RNA, except for the window bench, which measured 6.5×10^2 copies per mL. The authors said they could not make a definitive conclusion based on having one patient sample, but they attributed the limited transmission (only 1 environmental sample was found) to the use of air cleaning in the isolation rooms (12 air changes/hour) or to limited airborne transmission of SARS-CoV-2, though they acknowledged the possibility of indirect transmission through environmental surfaces, consistent with SARS-CoV.

Additionally, in a research letter (i.e., not peer-reviewed research) in *JAMA*, Ong, Tan, Chia, Lee, Ng, Wong, and Marimuthu (2020) conducted environmental assessments of 26 different sites in each of three patient rooms at a SARS-CoV-2 outbreak center in Singapore while patients were treated in those rooms. Samples from two patient rooms returned negative results for SARS-CoV-2 after two collection periods. In the third patient room, “13 (87%) of 15 room sites (including air outlet fans) and 3 (60%) of 5 toilet sites (toilet bowl, sink, and door handle) returning positive results. Anteroom and corridor samples were negative…. Only 1 [Personal Protective Equipment] swab, from the surface of a shoe front, was positive. All other PPE swabs were negative. All air samples were negative” (p. 1610). However, swabs of the air vent outlets were positive for SARS-CoV-2. Although the researchers acknowledged a limitation of only sampling a small part of the patient room air, they noted that air droplets in addition to feces were potential transmission avenues. The researchers called for strict environmental cleaning and hand hygiene protocols for environments where SARS-CoV-2 infected persons are and called for additional research.

Japan’s Taskforce for the COVID-19 Cruise Ship Outbreak (Taskforce for the COVID-19 Cruise Ship Outbreak & Yamagishi, 2020) prepared a preprint article investigating whether environmental surfaces were a leading cause of transmission for SARS-CoV-2 during a cruise ship outbreak in early 2020. This study tested environmental surface samples taken from common areas, cabins of confirmed cases, and cabins of non-cases. Samples were tested by rt-PCR. Case-cabins had been disinfected with a 5% hydrogen peroxide spray prior to the sampling and all sample areas were swabbed in high touch/traffic zones including light switches, doorknobs, toilet flush buttons, toilet seats, bathroom floor, armrests, television remote controls, telephones, desks, and bed pillows. SARS-CoV-2 RNA was found in 10% of the samples, which were taken 1-17 days after passengers left the cabin. All samples in which SARS-CoV-2 RNA was detected were from case-cabins. RNA was most often detected on the floor around the toilet (up to 17 days after passenger disembarking) and the bed pillows (up to 15 days after passenger disembarking) and there was no difference in detection proportion between cabin samples of symptomatic and asymptomatic passengers. The authors note that the storage transport and temperature may have affected viral isolation and researchers could not measure temperature and humidity throughout the ship. The authors conclude that the transmission risk of SARS-CoV-2 from symptomatic and asymptomatic passengers is similar and environmental surfaces could facilitate transmission through direct contact, however this requires further investigation. They suggest "Cleaning of surfaces with hydrogen peroxide-based products and communication messages demonstrating and emphasizing hand hygiene are essential to interrupting the chain of transmission during outbreaks." (p. 9).

Ye et al. (2020; article in press) evaluated the potential contamination of surfaces of 13 hospital function zones, five major objects, and 3 major PPE with SAR-CoV-2 in a hospital in Wuhan, China. Reverse transcription PCR (RT-PCR) was used for the detection of SAR-CoV-2. The results of the study revealed that of the 626 hospital environmental surface swabs collected, 13.6% were found to be positive for SARS-CoV-2. The most contaminated areas of the hospital were the specialized intensive care unit (ICU) for patients with novel coronavirus pneumonia (NCP) (31.9%), the Obstetric Isolation Ward for pregnant women with NCP (28.1%), and Isolation Ward for NCP (19.6%). The most contaminated objects were self-service printers (20%), desktops/keyboards (16.8%), and doorknobs (16.0%). SARS-CoV-2 was detected in 20.3% of hand sanitizer dispensers; 15.4% of gloves, and 1.7% of eye protection or face shields. The authors concluded that their study highlights the importance of environmental cleaning, strong infection prevention training and improved prevention precautions in minimizing the risk of the spread of SARS-CoV-2.

Human Tears

Jun and colleagues (2020) conducted a prospective study using RT-PCR analysis to determine whether SARS-CoV-2 is transmitted through tears. This small study included 17 COVID-19 patients from Singapore. Nasopharyngeal swabs and tear samples were collected. None of the patients had ocular symptoms and 14 patients had upper respiratory symptoms. Sixty-four samples were collected over a three-week period, none of which were successfully isolated, and all showed negative results for SARS-CoV-2. This study found no evidence of viral shedding via tears. The authors cited use of two laboratories analyzing samples using two different assays as well as small sample size as limitations of this study. They also noted that only tears were sampled rather than conjunctival tissue and concluded that their results suggest transmission through tears is low, but recommend future studies using more in-depth analysis and larger sample size are conducted.

3.2. Survival of SARS-CoV-2 on material surfaces through environmental attenuation

Several articles, primarily non-peer-reviewed, offer diverse findings related to the environmental attenuation of SARS-CoV-2 on diverse surfaces.

In "Master Question List for COVID-19 (caused by SARS-CoV-2)," a review of the literature, published by Department of Homeland Security Science and Technology Directorate (2020), it was concluded that, "SARS-CoV-2 can persist on surfaces for at least 3 days and on the surface of a surgical mask for up to 7 days depending on conditions" but also that "additional testing on SARS-CoV-2, as opposed to surrogate viruses, is needed to support initial estimates of stability" (p. 12).

Additionally, in a "pre-print" article (i.e., not peer-reviewed at this time), Pastorino and colleagues (2020) investigated the stability and infectivity of SARS-CoV-2 on polystyrene plastic, aluminum, and glass. The virus was put on various surfaces and analyzed over 96 hours at 45-55% humidity at 19-20 degrees Celsius (C) using a 106 TCID50/mL inoculum. Experiments were completed with and also without bovine serum albumine (BSA, 10 g/L), an interfering substance which mimics the protein content of body fluids. Each experiment was conducted three times. Virus viability decreased within two hours on all surfaces, however the viability was preserved on all surfaces in experiments using BSA. This is notable as it is meant to represent an infected patient depositing infection secretion. The authors noted that results between the surface type were unique, reporting "steady viability with a <1 $\log^{10}$ drop over 92 hours on polystyrene plastic… a 3.5 $\log^{10}$ decrease along 44 hours on glass, and… a sharp 6 $\log^{10}$ drop in less than 4 hours on aluminum (3, 4)" (p. 2). The authors concluded that protein concentrations in droplets increases the viability of SARS-CoV-2 and that contaminated fomites containing SARS-CoV-2 "play a significant role in the person-to-person dissemination," as it remained on surfaces for more than 96 hours (p. 2). The authors recommended surface cleaning be enforced and repeated to interfere in the transmission of the virus.

Chin and colleagues (2020) published a correspondence describing their examination of the stability of SARS-CoV-2 on different surfaces. They pipetted a 5 µL droplet of virus culture (~7.8 log unit of TCID50 per mL) on to a surface and left at room temperature with a relative humidity of 65%. They reported: "The inoculated objects retrieved at desired time-points were immediately soaked with 200 µL of virus transport medium for 30 mins to elute the virus" (p. 1). After a three-hour incubation, no infectious virus was detected on printing and tissue papers. No infectious virus was detected on treated wood and cloth on day 2 and on glass and banknote on day 4. The virus was very stable on stainless steel and plastic on which no infectious virus was detected on day 7. Lastly, SARS-CoV-2 was still detected on the outer surface of a surgical mask on day 7.

In a letter to the editor, van Doremalen and colleagues (2020) examined stability and decay rates of SARS-CoV-2 on cardboard, coppers, plastic, and stainless steel in comparison to SARS-CoV-1. Findings indicated that for copper, no viable SARS-CoV-2 was measured after 4 hours, compared to 8 hours for SARS-CoV-1 and the half-lives for the viruses were similar. No viable SARS-CoV-2 was measured on cardboard after 24 hours and after 8 hours for SARSCoV-1. Cardboard saw the most significant difference in the half-lives of the two viruses, with that of SARS-CoV-2 being longer than that of SARS-CoV-1. SARS-CoV-2 was more stable on stainless steel and plastic than on copper and cardboard. The virus remained viable on stainless steel after 48 hours; however, the virus titer reduced from $10^{3.7}$ to $10^{0.6}$ $TCID_{50}$. The median half-life of SARS-CoV-2 was 5.6 hours. SARS-CoV-2 remained viable on plastic after 72 hours and the virus titer reduced from $10^{3.7}$ to $10^{0.6}$ $TCID_{50}$. The median half-life of SARS-CoV-2 was 6.8 hours. The authors concluded that the stability of SARS-CoV-2 is similar to that of SARS-CoV-1 and thus, the epidemiologic characteristics that differ in the viruses may due to other factors.

These findings are presented by surface/material in the following table.

Surface or Material	Attenuation results	Source(s) & Methodology Details
Polystyrene plastic	<1 log^{10} drop over 92 hours on polystyrene plastic	Pastorino et al., 2020 - 45-55% humidity at 19-20 degrees Celsius (C) using a 106 TCID50/mL inoculum, with and also without bovine serum albumin
Aluminum	6 log^{10} drop in less than 4 hours on aluminum	Pastorino et al., 2020 - 45-55% humidity at 19-20 degrees Celsius (C) using a 106 TCID50/mL inoculum, with and also without bovine serum albumin
Glass	3.5 log^{10} decrease after 44 hours on glass	Pastorino et al., 2020 - 45-55% humidity at 19-20 degrees Celsius (C) using a 106 TCID50/mL inoculum, with and also without bovine serum albumin
	4 days - no infectious virus detected	Chin et al., 2020 - 5 µL droplet of virus culture (~7.8 log unit of TCID50 per mL) on to a surface and left at room temperature with a relative humidity of 65%
Wood	2 days – no infectious virus detected	Chin et al., 2020 - 5 µL droplet of virus culture (~7.8 log unit of TCID50 per mL) on to a surface and left at room temperature with a relative humidity of 65%
Paper (printing and tissue)	3 hours – no infectious virus detected	Chin et al., 2020 - 5 µL droplet of virus culture (~7.8 log unit of TCID50 per mL) on to a surface and left at room temperature with a relative humidity of 65%
Cloth	2 days - no infectious virus detected	Chin et al., 2020 - 5 µL droplet of virus culture (~7.8 log unit of TCID50 per mL) on to a surface and left at room temperature with a relative humidity of 65%
Banknote	4 days - no infectious virus detected	Chin et al., 2020 - 5 µL droplet of virus culture (~7.8 log unit of TCID50 per mL) on to a surface and left at room temperature with a relative humidity of 65%
Stainless Steel	7 days - no infectious virus detected	Chin et al., 2020 - 5 µL droplet of virus culture (~7.8 log unit of TCID50 per mL) on to a surface and left at room temperature with a relative humidity of 65%
	48 hours – still viable but virus titer reduced from $10^{3.7}$ to $10^{0.6}$ $TCID_{50}$	van Doremalen et al., 2020 - Aerosols (<5 µm) containing SARS-CoV-2 (105.25 50% tissue-culture infectious dose [TCID50] per milliliter)
Plastic	7 days - no infectious virus detected	Chin et al., 2020 - 5 µL droplet of virus culture (~7.8 log unit of TCID50 per mL) on to a surface and left at room temperature with a relative humidity of 65%

	72 hours – still viable but virus titer reduced from $10^{3.7}$ to $10^{0.6}$ $TCID_{50}$	van Doremalen et al., 2020 - Aerosols (<5 μm) containing SARS-CoV-2 (105.25 50% tissue-culture infectious dose [TCID50] per milliliter)
Surgical Mask	Virus still detected 7 days later	Chin et al., 2020 - 5 μL droplet of virus culture (~7.8 log unit of TCID50 per mL) on to a surface and left at room temperature with a relative humidity of 65%
Cardboard	24 hours – no infectious virus detected	van Doremalen et al., 2020 - Aerosols (<5 μm) containing SARS-CoV-2 (105.25 50% tissue-culture infectious dose [TCID50] per milliliter)
Copper	4 hours – no infectious virus detected	van Doremalen et al., 2020 - Aerosols (<5 μm) containing SARS-CoV-2 (105.25 50% tissue-culture infectious dose [TCID50] per milliliter)

3.3. Effectiveness of Prevention and Decontamination Measures

The research literature explored the efficacy of a variety of prevention and decontamination measures to reduce transmission of SARS-CoV-2, including thermal treatment, personal protective equipment (PPE), hand hygiene, plastic barriers, light exposure, sodium dicholoroisocyanurate, ventilation and open space, and surface cleaners and disinfectants (including pH).

On March 19, 2020, The World Health Organization (WHO) provided prevention and decontamination recommendations for use with COVID-19. This guidance was adapted from previous guidelines developed for use against the Middle East respiratory syndrome coronavirus (MERS-CoV) infection and severe acute respiratory syndrome (SARS). Precautions for patient and medical staff were outlined for hand washing, respiratory hygiene, use of personal protective equipment (PPE), environmental disinfecting, and equipment sterilization were outlined. In particular, respiratory hygiene recommendations included 1) covering nose and mouth (with tissue or elbow) when coughing or sneezing, 3) offering masks for people suspected of having COVID-19 for use while in public areas and 3) performing hand hygiene after contact with respiratory secretions. In addition, the guidance supports the application of WHO's My 5 Moments for Hand Hygiene approach, such as either cleansing hands with an alcohol-based disinfectant or with soap and water (the latter when hands are visibly soiled). Further, general recommendations for contact/droplet and airborne precautions included, but were not limited to:

- adequately ventilated rooms
- using a medical mask
- wearing goggles or face shield to avoid contamination of mucous membranes
- using gloves
- avoiding touching eyes, nose, or mouth with potentially contaminated gloved or bare hands
- routinely cleaning and disinfecting surfaces.

Jin et al. (2020) drafted guidelines for healthcare professionals in alignment with rapid advice methodology as well as general rules of WHO guideline development.

Recommendations for disease screening and population prevention, diagnosis, treatment and control, nosocomial infection prevention and control, and disease nursing of the 2019-nCoV are described. Pulling from SARS, MERS, and influenza insights, guidelines were categorized into strong and weak groupings. Environmental requirements discussed for suspected cases included, but were not limited to, room ventilation, hygiene practices, and appropriate PPE usage. However, this work had several limitations such as 1) restricted time to consider the variety of clinical issues for Covid-19, 2) findings being gleaned from an indirect data search, and 3) recommendation categorization was based on previous guidelines and experts' experience.

3.3.1. Thermal Treatment

In a letter to the editor (i.e., not peer-reviewed research), Kampf, Voss, and Scheithauer (2020) presented a small-scale literature review (n=10 articles) of articles presenting original data related to the effectiveness of thermal disinfection strategies for human and zoonotic coronaviruses. The authors concluded that coronavirus infectivity was found to be reduced by at least 4 log^{10} after 30 minutes at 60 degrees Celsius, 15 minutes at 65 degrees Celsius, and one minute at 80 degrees Celsius. The authors cited one article that found the SARS-CoV nucleocapsid protein was completely denatured after 10 minutes in 55 degrees Celsius. With regard to limitations, the authors noted that the articles tested coronaviruses in suspension, not on dry surfaces, but argued that the effects were unlikely to be different. In conclusion, the authors argued that heat treatment at the temperatures specified may be used to safely clean masks for healthcare workers if a shortage arose during the COVID-19 outbreak. However, they acknowledged that they did not test heat treatment on masks, so mask function after heat treatment was not considered. The authors recommended that healthcare organizations test the impact of heat treatment on different mask types since different masks may react differently.

In their correspondence, Chin and colleagues (2020) described their examination of the stability of SARS-CoV-2 at different temperatures, they found that the virus is highly stable at 4°C but is susceptible to heat. There was an approximately 0.7 log-unit reduction of infectious titer on day 14 at 4°C; however, when the incubation temperature was increased to 70°C, virus inactivation was only to 5 mins.

3.3.2. Personal Protective Equipment (PPE)

In "Master Question List for COVID-19 (caused by SARS-CoV-2)," a literature review published by Department of Homeland Security Science and Technology Directorate, it was concluded that although "masks may be effective at slowing transmission," "The effectiveness of PPE for SARS-CoV-2 is currently unknown, and data from other related coronaviruses are used for guidance" and "most PPE recommendations have not been made on SARS-CoV-2 data, and comparative efficacy of different PPE for different tasks (e.g., intubation) is unknown" (p. 14).

Cheng et al. (2020) reported on the emergency response and infection control preparedness in a Hong Kong hospital, where 413 healthcare workers were in contact with patients infected with SARS-CoV-2, including 11 staff with unprotected exposure; however zero cases of infection transmission to healthcare workers at the hospital was reported. The authors attributed this lack of transmission to a bundled prevention approach of mask wearing by all staff and visitors and enhanced hand hygiene.

In their literature review of SARS-CoV-2 transmission risk for healthcare workers, Ferioli et al. (2020) recommended that healthcare workers can reduce exposure to exhaled droplets from infected patients by frequent hand washing with alcohol-based detergent (>65%) or soap and water, especially after contact with respiratory fluids. Medical or surgical masks that cover nose and mouth were recommended, not fabric masks, and wearers were encouraged to follow directions for proper wear. In healthcare settings, interaction with people with respiratory symptoms (including cleaners) was recommended to involve medical mask, gloves, disposable gowns, and face shield. Physical barriers were also recommended to reduce exposure, such as glass or plastic windows.

3.3.3. Hand Hygiene

In “Master Question List for COVID-19 (caused by SARS-CoV-2),” a literature review published by Department of Homeland Security Science and Technology Directorate, it was concluded that soap and water and hand sanitizers are effective at decontaminating hands of SARS-CoV-2.

The report of a Hong Kong hospital’s response by Cheng et al. (2020) attributed the lack of transmission of SARS-CoV-2 to 413 healthcare workers to a bundled prevention approach of mask wearing and enhanced hand hygiene, which was monitored for compliance.

3.3.4. Plastic Barriers

Matava, Yu, and Denning (2020), in a letter to the editor (i.e., not peer-reviewed research), the authors reported on a recent experiment in which they sought to ascertain if clear plastic drapes could be used to reduce the transmission of aerosolized saliva during extubation procedures, and thus minimize the exposure of healthcare workers to SARS-CoV-2 during extubation. The aerosolization was simulated using a mannequin, air gun, and a substance visible under ultraviolet light, and three conditions were produced: without plastic drapes, with a single plastic drape over the patient's head and the tube, and a three-drape set up that included a drape under the patient's head, one over the torso, and one over the patient's head. Visual inspection of the results indicated that plastic drapes reduced the aerosolized spread of contaminated saliva, with the three-drape intervention proving even more effective than the single-drape barrier. Although, the authors concluded that the experiment offered proof of concept of the aerosolization patterns during extubation and that the use of simple, inexpensive plastic drapes could protect healthcare workers from aerosolized transmission of SARS-CoV-2, the authors also noted the limitations of their "low-fidelity" experimental design and that using a simulant may not reflect the exact aerosolization patterns of SARS-CoV-2 during extubation.

3.3.5. Light Exposure

In a research article that has only been pre-approved for peer-review by *Virology* and has not completed full peer-review for scientific acceptability, Buonanno, Welch, Shuryak, and Brenner (2020) conducted an experiment to test the effects of far-UVC light on coronaviruses from two subgroups: alpha (HCoV-229E) and beta (HCoV-OC43), without damaging human tissue. In their results, the authors stated, "We found that low doses of, respectively 1.7 and 1.2 mJ/cm2 inactivated 99.9% of aerosolized alpha coronavirus 229E and beta coronavirus OC43. Based on these results for the beta HCoV-OC43 coronavirus, continuous far-UVC exposure in public locations at the currently recommended exposure limit (3 mJ/cm2/hour) would result in 99.9% viral inactivation in ~ 25 minutes. Increasing the far- UVC intensity by, say, a factor of 2 would halve these disinfection times, while still maintaining safety. As all human coronaviruses have similar genomic size, a key determinant of radiation sensitivity, it is realistic to expect that far-

UVC light will show comparable inactivation efficiency against other human coronaviruses, including SARS-CoV-2" (np). Note that the authors did not test the intervention on SARS-CoV-2 in particular.

3.3.6. Sodium dichloroisocyanurate

In their research letter (i.e., non-peer-reviewed) in *JAMA*, Ong et al. (2020), reported that successful decontamination was achieved in hospital rooms of patients diagnosed with SARS-CoV-2 infection through “Twice-daily cleaning of high-touch areas…using 5000 ppm of sodium dichloroisocyanurate” and cleaning the floor “daily using 1000 ppm of sodium dichloroisocyanurate” (p. 1610). However, the authors acknowledged the limitations, “viral culture was not done to demonstrate viability” and “due to operational limitations during an outbreak, methodology was inconsistent and sample size was small” (p. 1611).

3.3.7. Ventilation and open space

In a preprint article that has not undergone peer review yet, Liu et al. (2020) presented the results of an aerosol study to quantify concentrations, aerodynamic size distributions, and dry deposition rate of airborne SARS-CoV-2. The authors collected 35 aerosol samples collected from patient and staff areas in two hospitals and outdoor public areas in Wuhan, China during the SARS-CoV-2 outbreak. Three types of aerosol samples were collected: total suspended particle, size segregated, and deposition aerosols. The authors found that ample ventilation and open space was found to be effective at limiting aerosol transmission of SARS-CoV-2. Specifically, negative pressure ventilation and high air exchange rate were found effective at minimizing the concentration of airborne SARS-CoV-2. The authors concluded that there is low risk of transmission in open, outdoor spaces. The authors also confirmed that "the aerosol transmission as an important pathway for surface contamination" in small spaces, such as bathrooms. The authors noted two exceptions to the finding of undetectable or low concentrations of SARS-CoV-2 in outdoor public spaces. First, the exceptions occurred close to building entrances where people congregated and passed through with frequency, and second, the authors suggested that the positive aerosol samples in these areas could be attributed asymptomatic carriers of SARS-CoV-2.

Additionally, a cross-sectional study conducted by Japan’s Taskforce for the COVID-19 Cruise Ship Outbreak (2020) tested environmental surface and air samples from a cruise ship that had experienced an outbreak of COVID-19. One to 17 days after passengers had disembarked, non-case-cabins next to case-cabins, as well as case-cabins were selected for air sampling. Samples were collected through a special gelatin filter which was placed on the bed and toilet seat. SARS-CoV-2 was not detected in any of the air samples. The authors conclude that stopping the recirculation of air may have prevented airborne transmission, however this requires further investigation.

3.3.8. Surface cleaners and disinfectants

In “Master Question List for COVID-19 (caused by SARS-CoV-2),” a literature review published by Department of Homeland Security Science and Technology Directorate, it was concluded that, “Soap and water, as well as common alcohol and chlorine-based cleaners, hand sanitizers, and disinfectants are effective at inactivating SARS-CoV-2 on hands and surfaces” (p. 13).

Chin and colleagues (2020) investigated the viricidal effects of various disinfectants (including household bleach, hand soap solution, ethanol, povidone-iodine, chloroxylenol, chlorhexidine, and benzalkonium chloride). With the exception of a 5-minute incubation with hand soap, SARS-CoV-2 was undetectable after 5-, 15-, and 30-minute incubations at room temperature for all the disinfectants, demonstrating susceptibility of the virus to these common disinfectants.

Chin et al. (2020) also examined the stability of SARS-CoV-2 across a wide range of pH values. Findings indicated that the virus was very stable from pH 3-10.

4. Conclusion

The primary finding of this exploratory preliminary search is that there exists a limited amount of peer-reviewed scientific research related to SARS-CoV-2 specifically and the project research questions, and thus additional high-quality experimental science focused on SARS-CoV-2 is needed to ensure accurate guidelines. The multiple non-peer-reviewed works identified through the organic, targeted search process undertaken for this report suggest that although some scientific research is being conducted and presented, much of it remains nascent and requires additional vetting by the scientific community, both in terms of rigorous peer-review and conducting additional studies to produce converging and/or diverging results.

This appears especially to be the case for studies of the environmental attenuation of SARS-CoV-2 on surfaces and materials, as none of the articles in section 3.2 were peer-reviewed scholarly publications. These articles present a variety of findings suggesting the virus can attenuate anywhere from two hours to seven days, depending on numerous variables, such as the surface/material type, environmental temperature and humidity, presence of bodily substances fluids, etc.

Furthermore, although some early guidance has been provided about how the virus can be spread as well as prevention and contamination guidelines to prevent such spreading, much of the guidance identified in this review seems to arise from literature reviews related to the coronaviruses that caused past outbreaks (e.g., SARS and MERS) or novel research that has not undergone scientific peer review. Articles in this preliminary search reported that SARS-CoV-2 may travel by water droplets and feces, some studies reported no detection of the virus in air samples gathered from patients with SARS-CoV-2 directly as well as air in their rooms, and others reported finding evidence of the virus on surfaces in proximity to people infected with SARS-CoV-2. The studies reported here also explored the efficacy of diverse prevention and decontamination measures to reduce transmission of SARS-CoV-2, including thermal treatment, personal protective equipment (PPE), hand hygiene, plastic barriers, light exposure, sodium dicholoroisocyanurate, ventilation and open space, and surface cleaners and disinfectants (including pH); however, these articles rarely consisted of peer-reviewed experimental research focused specifically on SARS-CoV-2. As such, the findings of this review neither confirm nor discredit the prevention and decontamination guidelines currently provided, but this review does indicate that additional experimental research of SARS-CoV-2 specifically is needed to help clarify the distinctions in viricidal technique required for SARS-CoV-2 compared to other related pathogens to ensure the accuracy of those guidelines.

Battelle recommends additional literature review using a systematic search process to supplement this preliminary review. A larger sample of research articles focused on SARS-CoV-2 has already been identified in collaboration with Battelle's library experts. Such a review will build upon these preliminary findings to provide a fuller, more detailed accounting of the SARS-CoV-2 research conducted to date, which can be used to inform Battelle's laboratory experiments and the library operations guidelines to be produced for local libraries.

5. References

Buonanno, M., Welch, D., Shuryak, I., and Brenner, D. J. (2020). Far-UVC light efficiently and safely inactivates airborne human coronaviruses. *Nature Research*, 10.21203/ rs.3.rs-25728/v1. https://doi.org/10.21203/rs.3.rs-25728/v1

Cheng, V. C., Wong, S. C., Chen, J. H., Yip, C. C., Chuang, V. W., Tsang, O. T., ... & Yuen, K. Y. (2020). Escalating infection control response to the rapidly evolving epidemiology of the Coronavirus disease 2019 (COVID-19) due to SARS-CoV-2 in Hong Kong. *Infection Control & Hospital Epidemiology*, 1-6. https://doi.org/10.1017/ice.2020.58

Chin, A., Chu, J., Perera, M., Hui, K., Yen, H. L., Chan, M., ... & Poon, L. (2020). Stability of SARS-CoV-2 in different environmental conditions. *medRxiv*. https://doi.org/10.12998/wjcc.v8.i8.1391

DHS Science and Technology Directorate (2020). DHS Science and Technology, Master Question List for COVID-19 (caused by SARS-CoV-2) Weekly Report. https://www.dhs.gov/publication/st-master-question-list-covid-19

Faridi, S., Niazi, S., Sadeghi, K., Naddafi, K., Yavarian, J., Shamsipour, M., ... & Momeniha, F. (2020). A field indoor air measurement of SARS-CoV-2 in the patient rooms of the largest hospital in Iran. *Science of The Total Environment*, 138401. https://doi.org/10.1016/j.scitotenv.2020.138401

Ferioli, M., Cisternino, C., Leo, V., Pisani, L., Palange, P., & Nava, S. (2020). Protecting healthcare workers from SARS-CoV-2 infection: practical indications. *European Respiratory Review*, *29*(155). https://doi.org/10.1183/16000617.0068-2020

Guo, Z. D., Wang, Z. Y., Zhang, S. F., Li, X., Li, L., Li, C., ... & Zhang, M. Y. (2020). Aerosol and surface distribution of severe acute respiratory syndrome coronavirus 2 in hospital wards, Wuhan, China, 2020. *Emerg Infect Dis*, *26*(7). https://doi.org/10.3201/eid2607.200885

Ijaz, M. K., Brunner, A. H., Sattar, S. A., Nair, R. C., & Johnson-Lussenburg, C. M. (1985). Survival characteristics of airborne human coronavirus 229E. *Journal of General Virology*, *66*(12), 2743-2748. https://doi.org/10.1099/0022-1317-66-12-2743

Jin, Y. H., Cai, L., Cheng, Z. S., Cheng, H., Deng, T., Fan, Y. P., ... & Han, Y. (2020). A rapid advice guideline for the diagnosis and treatment of 2019 novel coronavirus (2019-nCoV) infected pneumonia (standard version). *Military Medical Research*, *7*(1), 4. https://dx.doi.org/10.1186%2Fs40779-020-0233-6

Kampf, G., Voss, A., & Scheithauer, S. (2020). Inactivation of coronaviruses by heat. *Journal of Hospital Infection*. https://doi.org/10.1016/j.jhin.2020.03.025

Liu, Y., Ning, Z., Chen, Y., Guo, M., Liu, Y., Gali, N. K., ... & Liu, X. (2020). Aerodynamic characteristics and RNA concentration of SARS-CoV-2 aerosol in Wuhan hospitals during COVID-19 outbreak. *BioRxiv*. https://doi.org/10.1038/s41586-020-2271-3

Matava, C. T., Yu, J., & Denning, S. (2020). Clear plastic drapes may be effective at limiting aerosolization and droplet spray during extubation: implications for COVID-19. *Canadian Journal of Anesthesia/Journal canadien d'anesthésie*, 1-3. https://doi.org/10.1007/s12630-020-01649-w

Ong, S. W. X., Tan, Y. K., Chia, P. Y., Lee, T. H., Ng, O. T., Wong, M. S. Y., & Marimuthu, K. (2020). Air, surface environmental, and personal protective equipment contamination by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) from a symptomatic patient. *Jama*, *323*(16), 1610-1612. https://doi.org/10.1001/jama.2020.3227

Pastorino, B., Touret, F., Gilles, M., de Lamballerie, X., & Charrel, R. (2020). Prolonged viability of SARS-CoV-2 in fomites. https://osf.io/7etga

Jun, I. S. Y., Anderson, D. E., Kang, A. E. Z., Wang, L. F., Rao, P., Young, B. E., ... & Agrawal, R. (2020). Assessing viral shedding and infectivity of tears in coronavirus disease 2019 (COVID-19) patients. *Ophthalmology*. https://doi.org/10.1016/j.ophtha.2020.03.026

Taskforce for the COVID-19 Cruise Ship Outbreak, Yamagishi, T. (2020). Environmental sampling for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) during a coronavirus disease (COVID-19) outbreak aboard a commercial cruise ship. medRxiv 2020.05.02.20088567; doi: https://doi.org/10.1101/2020.05.02.20088567

Van Doremalen, N., Bushmaker, T., Morris, D. H., Holbrook, M. G., Gamble, A., Williamson, B. N., ... & Lloyd-Smith, J. O. (2020). Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. *New England Journal of Medicine*, *382*(16), 1564-1567. https://doi.org/10.1056/nejmc2004973

World Health Organization. (2020). Coronavirus disease (COVID-19) technical guidance: Infection prevention and control. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance/infection-prevention-and-control

Ye, G., Lin, H., Chen, L., Wang, S., Zeng, Z., Wang, W., ... & Yang, Z. (2020). Environmental Contamination of SARS-CoV-2 in Healthcare Premises. *Journal of Infection.* https://doi.org/10.1016/j.jinf.2020.04.034