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Rapid Review Update 1: What is known about how long the virus can survive with potential for infection on surfaces found in community settings?

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Please Note: An update of this review may be available. Access the most current version of this review by visiting the National Collaborating Centre for Methods and Tools COVID-19 Rapid Evidence Service at the above link.

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This update was completed with contributions by colleagues in the COVID-19 Rapid Evidence Service at Public Health England.

The authors declare they have no conflicts of interest to report.

Executive Summary

Background

As community transmission of the coronavirus disease 2019 (COVID-19) continues worldwide, it is important to understand the role that indirect transmission via surfaces may play in community settings.

This updated rapid review was produced to support public health decision makers' response to the COVID-19 pandemic. This review seeks to identify, appraise, and summarize emerging research evidence to support evidence-informed decision making.

This rapid review includes evidence available up to December 31, 2020 to answer the question: **What is known about how long the virus can survive with potential for infection on surfaces found in community settings?**

What Has Changed in This Version?

- Since the last version of this review (July 31, 2020), the body of evidence has grown substantially. To be able to complete this updated rapid review, we have refined the research question to surfaces found in community settings (i.e., not hospital/clinical settings). This has resulted in 18 studies that were included in the original review being excluded in this update. A list of excluded references is available here.
- This update includes four new syntheses, one update to a previously included synthesis, and 22 new single studies.

Key Points

- Across several syntheses and prevalence studies, there is consistent evidence that fragments of SARS-CoV-2 can be detected on surfaces in community settings for up to seven days, the certainty of evidence is considered moderate (GRADE), and it is possible that findings may change as new information becomes available. However, most of these studies measure viral genetic material, so did not distinguish between live virus and dead virus or viral fragments. Only one study measured viable virus (that which has potential to infect) in samples and found none to be present.
- Overall, viral fragments can be detected on surfaces, but these fragments may not be viable, with the certainty of evidence considered low (GRADE) and findings may change as new information becomes available.
- Of the studies that reported whether cleaning of surfaces had occurred prior to sampling, disinfecting / cleaning procedures consistently decreased or eliminated detection of SARS-CoV-2 fragments. The certainty of the evidence is considered moderate (GRADE), and it is possible that findings may change as new information becomes available.

- Findings from laboratory-based studies indicate SARS-CoV-2 can remain viable longer on smoother surfaces such as plastic or steel than cardboard or cotton. However often with starting concentrations much higher than found in the environment. There is wide variation in the length of times reported but there is indication of increased stability at lower temperatures (such as 4°C) and more rapid decay with increasing temperatures. Study quality cannot be assessed with GRADE as this evidence is from laboratory studies only, and the applicability of these findings to real world settings is unknown.

Overview of Evidence and Knowledge Gaps

- Several studies that collected surface samples in community settings have detected fragments of SARS-CoV-2 by real-time RT-PCR in samples from a variety of surfaces, particularly bedrooms, bathrooms and high-touch surfaces such as door handles.
- In agreement with findings from other syntheses, the likelihood of finding fragments of SARS-CoV-2 on surfaces sampled in community settings has varied across studies. It is not possible to determine the extent to which this variability is due to the different methods of sampling used, which affect the chance of detecting virus particles. For example, some studies used random surface sampling, yet most used 'high-touch' surfaces to maximize chance of detection.
- Although virus particles have been detected, the methods used for testing in many of these studies is not as rigorous as the current gold standard test (which requires three RNA targets to be amplified by real-time RT-PCR (Corman et al., 2020), as they have only used one or two RNA targets). Moreno et al. found most positive samples tested positive for only one of the three RNA targets, yet Di Carlo et al. found none of their samples to have at least two positive targets. Most studies do not distinguish between live virus and dead virus or viral fragments.
- Only one prevalence study, by Döhla et al. attempted to detect viable virus (live virus that has retained potential to infect) by viral culture test, and did not detect any, despite finding positive samples by real-time RT-PCR (suggesting these positive samples may not have been viable virus). Therefore, there appears to be low risk of infection from touching a contaminated surface, although the evidence is very limited due to only one study using a viral culture test for live virus.
- Several disinfecting or cleaning procedures were reported to occur after contamination but prior to sampling, and consistently decrease or eliminate real-time RT-PCR positive SARS-CoV-2 samples. Of the eight studies that explicitly stated that surfaces had been cleaned before sample collection, five found only negative samples and three a small number of positive samples. Most studies had varied, or were not explicit on, cleaning practices used, however the presence of a cleaning procedure consistently reduced the detection of viral particles.
- Under controlled laboratory conditions, some using high initial titres, the length of time viable virus was detectable (by viral culture test) on non-porous (hard) surfaces ranged from three to 28 days. On porous surfaces such as cloth, those which tested a range of different time points found that the majority was absorbed soon after application but could remain detectable from three hours to 14 days. Laboratory studies often use starting concentrations that are orders of magnitude higher than those observed in the environment. These starter concentrations will influence survival times, making it difficult to generalize findings from laboratory studies to real world settings.

- Seven laboratory studies investigated the effect of temperature on survival of viable SARS-CoV-2. Temperatures from 4°C to 70°C were tested. Six studies found there to be increased stability at lower temperatures, with faster decay as temperatures increase; one study found the highest stability at 30°C with the virus being most stable at room temperature.
- One study investigated relative humidity on survival of the virus, and found fastest decay at 65% relative humidity, and slower decay at both lower (40%) and higher (85%) relative humidity. However, the applicability of these findings to real world settings is unknown.

Methods

Research Question

What is known about how long the virus can survive with potential for infection on surfaces found in community settings?

Search

On January 4, 2021, the following databases were searched using key terms "indirect transmission", "fomite", "surface", and "touch" with date limits of Dec 31, 2021:

- MEDLINE
- Embase
- Trip Medical Database
- COVID-19 Evidence Alerts from McMaster PLUS™
- Public Health +
- COVID-19 Living Overview of the Evidence (L·OVE)
- McMaster Health Forum
- Prospero Registry of Systematic Reviews
- MedRxiv preprint server
- NCCMT COVID-19 Rapid Evidence Reviews
- NCCDH Equity-informed Responses to COVID-19
- NCCEH Environmental Health Resources for the COVID-19 Pandemic
- NCCID Disease Debrief
- NCCIH Updates on COVID-19
- NCCHPP Public Health Ethics and COVID-19
- Uncover (USHER Network for COVID-19 Evidence Reviews)
- Centers for Disease Control and Prevention's Morbidity and Mortality Weekly Report (MMRW)
- Institute national d'excellence en santé et en services sociaux (INESSS)
- BC Centre for Disease Control (BCCDC)
- Public Health Ontario
- Institut national de santé publique du Québec (INSPQ)
- Alberta Health Service's COVID-19 Resources for AHS Staff & Health Professionals

A copy of the full search strategy is available at this link.

What has changed in the methods for this version?

The body of literature for this topic has expanded significantly since the last version of this review. To complete a timely, focused synthesis of the evidence, the inclusion and exclusion criteria were refined to exclude studies conducted in clinical or hospital settings. Several studies that were previously included in this review have now been excluded; the list of excluded references is available at this link. This review provides a synthesis of evidence for transmission of the virus that causes COVID-19 via surfaces commonly found in community settings.

Study Selection Criteria

The search results were first screened for recent guidelines and syntheses. Single studies were included if no syntheses were available, or if single studies were published after the search was conducted in the included syntheses. English-language, peer-reviewed sources and sources published ahead-of-print before peer review were included. Surveillance sources were excluded. English-language, peer-reviewed sources and sources published ahead-of-print before peer review were included. When available, findings from syntheses and clinical practice guidelines are presented first, as these take into account the available body of evidence and, therefore, can be applied broadly to populations and settings.

	Inclusion Criteria	Exclusion Criteria
Population	Inanimate surfaces	Clinical settings Hospital settings
Intervention	SARS-CoV-2 exposure	Exposure through close contact with an infected individual
Comparisons	-	Laboratory studies where comparisons of different disinfection/cleaning products was primary objective
Outcomes	Detection of SARS-CoV-2 virus or RNA COVID-19 infection	

Data Extraction and Synthesis

Data relevant to the research question, such as study design, setting, location, population characteristics, interventions or exposure and outcomes were extracted when reported. We synthesized the results narratively due to the variation in methodology and outcomes for the included studies.

Appraisal of Evidence Quality

We evaluated the quality of included evidence using critical appraisal tools as indicated by the study design below. Quality assessment was completed by one reviewer and verified by a second reviewer. Conflicts were resolved through discussion. For some of the included evidence a suitable quality appraisal tool was not found, or the review team did not have the expertise to assess methodological quality. Studies for which quality appraisal has not been conducted are noted within the data tables.

Study Design	**Critical Appraisal Tool**
Synthesis	Assessing the Methodological Quality of Systematic Reviews (AMSTAR) AMSTAR 1 Tool
Prevalence	Joanna Briggs Institute (JBI) Checklist for Prevalence Studies

Completed quality assessments for each included study are available on request.

The Grading of Recommendations, Assessment, Development and Evaluations (GRADE) approach was used to assess the certainty in the findings based on eight key domains.

In the GRADE approach to quality of evidence, **observational studies,** as included in this review, provide **low quality** evidence, and this assessment can be further reduced based on other domains:

- High risk of bias
- Inconsistency in effects
- Indirectness of interventions/outcomes
- Imprecision in effect estimate
- Publication bias

and can be upgraded based on:

- Large effect
- Dose-response relationship
- Accounting for confounding.

The overall certainty in the evidence for each outcome was determined taking into account the characteristics of the available evidence (observational studies, some not peer-reviewed, unaccounted-for potential confounding factors, different tests and testing protocols, lack of valid comparison groups). A judgement of 'overall certainty is very low' means that the findings are very likely to change as more evidence accumulates.

Findings

Summary of Evidence Quality

In this update, four new syntheses, one update to a previously included synthesis, 22 new single studies were identified, and 18 studies were deemed ineligible for a total of 41 publications included in this review. The quality of the evidence included in this review is as follows:

Research Question	Evidence included		Overall certainty in evidence
What is known about how long the virus can survive with potential for infection on surfaces found in community settings?	Completed syntheses In progress syntheses Single studies	7 2 32	Low-moderate

Warning

Given the need to make emerging COVID-19 evidence quickly available, many emerging studies have not been peer reviewed. As such, we advise caution when using and interpreting the evidence included in this rapid review. We have provided a summary of the quality of the evidence as low, moderate or high to support the process of decision making. Where possible, make decisions using the highest quality evidence available.

Important to this question, we did not assess the methodological quality of laboratory-based studies. Due to the technical nature of these studies, we highly recommend consulting a content-area expert to inform decision making.

Table 1: Syntheses

Reference	Date Released	Description of Included Studies	Summary of Findings	Quality Rating: Synthesis	Quality Rating: Included Studies
New evidence reported March 5, 2021					
Bedrosian, N., Mitchell, E., Rohm, E., Rothe, M., Kelly, C., String, G., & Lantagne, D. (2020). A systematic review of surface contamination, stability, and disinfection data on SARS-CoV-2 (through July 10, 2020). *Environmental Science and Technology*. Epub ahead of print.	Nov 23, 2020 (Search completed Jul 10, 2020)	This review included: • 35 studies on surface contamination • 16 studies on surface stability • 27 studies on surface disinfection	Surfaces contamination in the community: 2.5% of household surfaces positive to SARS-CoV-2; 14% in non-household accommodation; and 14% in outdoor settings (including 25% high-touch surfaces and 23% hard furniture). SARS-CoV-2 half-life: 2.3-17.9 hours on stainless steel; 2.3-15.3 hours on plastic; 2.3-15.3 hours on nitrile. Half-life decreases as temperature and humidity increase. A 99.9% virus reduction can be obtained with sunlight, ultraviolet light, ethanol, hydrogen peroxide and hypochlorite. Knowledge gap on the contribution of fomite to SARS-CoV-2 transmission.	Low	Not reported
Bueckert, M., Gupta, R., Gupta, A., Garg, M., & Mazumder, A. (2020). Infectivity of SARS-CoV-2 and other coronaviruses on dry surfaces: Potential for indirect transmission. *Materials, 13*(22), 5211.	Nov 18, 2020 (Search date not reported)	This review included 26 studies, of which 15 were related to SARS-CoV-2. Probably all laboratory-based studies, although not clearly stated	Overall, porous substrates seem to inactivate SARS-CoV-2 faster than non-porous material (with some exceptions, such as N-95 and surgical masks on which SARS-CoV-2 appear to be remarkably stable). Correlation between material wettability and SARS-CoV-2 stability. Cotton and cellulose-based materials usually attenuate SARS-CoV-2 quicker than other materials (besides copper). SARS-CoV-2 persistence inversely related to temperature and humidity, and sunlight might inactivate the virus.	Low	Not reported

Fernández-Raga, M., Diaz-Marugan, L., Garcia Escolano, M., Bort, C., & Fanjul, V. (2020). SARS-CoV-2 viability under different meteorological conditions, surfaces, fluids and transmission between animals. *Environmental Research, 192*, 110293.	Oct 2, 2020 (Search completed Jun 29, 2020)	Approximately 6 studies were included related to SARS-CoV-2, although this is not clear	SARS-CoV-2 can stay for a variable period on different surfaces (from hours to days) maintaining its infective potential. However, touching a contaminated surface is only infective if contact with the surface ends up in mucosal membranes.	Low	Not reported
Meyerowitz, E. A., Richterman, A., Gandhi, R. T., & Sax, P. E. (2020). Transmission of SARS-CoV-2: A review of viral, host, and environmental factors. *Annals of Internal Medicine, 174*(1), 69-79.	Sep 17, 2020 (Search completed Sep 7, 2020)	This review included: • 1 laboratory-based study • 18 studies sampling contaminated environmental surfaces	There is no conclusive evidence for fomite or direct contact transmission of SARS-CoV-2 in humans, as reports suggesting fomite transmission are circumstantial (e.g., infected persons reporting no direct contact with a case, suggesting transmission via shared common facilities). Authors suspect the levels of viral RNA or live virus remaining on surfaces are unlikely to cause infection.	Low	Not reported
Usher Institute. (2020, Aug 15). *Summary: What is the evidence for indoor transmission of SARS-CoV-2?*	Aug 15, 2020 (Search completed May 21, 2020)	This review included 66 studies (to answer a range of questions). Number of studies relating to surfaces or types of study not reported	Laboratory-based studies suggest the virus may persist longer on smooth surfaces, such as plastic or stainless steel (up to 72 or 48 hours, respectively), than cardboard (up to 24 hours); and at low temperatures (highly stable at 4°C, not at 70°C) and damp conditions. Although viral RNA was detected on a range of objects in clinical and non-clinical settings, 3 studies which quantified the amount of virus present found minimal amounts. One epidemiological study reported fomite transmission, through occupying the same seat as the index case in a church.	Low ***NOT PEER REVIEWED***	Low

Previously reported evidence					
Fiorillo, L., Cervino, G., Matarese, M., D'Amico, C., Surace, G., Paduano, V., … Cicciù, M. (2020). COVID-19 Surface Persistence: A Recent Data Summary and Its Importance for Medical and Dental Settings. *International Journal of Environmental Research and Public Health*, *17*(9), 3132.	Apr 30, 2020 (Search date not reported)	This review included 4 laboratory-based studies, only one focused on SARS-CoV-2 (also included above).	SARS-CoV-2 persisted longest on plastic and stainless steel. The virus was not detectable after 4 hours on copper and 24 hours on cardboard. These findings are consistent with other coronaviruses.	Moderate	Not reported
National Academies of Sciences, Engineering, and Medicine. (2020, Mar 27). *Rapid expert consultation update on SARS-CoV-2 surface stability and incubation for the COVID-19 pandemic*.	Mar 27, 2020 (Search date not reported)	This review included: • Experimental laboratory-based studies • Prevalence studies	Two lab-based studies were described, as well as preliminary results from in-progress studies via personal communication. SARS-CoV-2 showed greater stability on smooth surfaces (glass, banknote, stainless steel, plastic); no infectious virus was detected after 4-7 days. Also, infectious virus was detectable on the outer layer of a surgical mask after 7 days. Across prevalence studies, there were variable rates of surface samples testing positive for SARS-CoV-2 primarily using reverse transcriptase-polymerase chain reaction (RT-PCR) for testing. Samples across studies were collected both prior to and after cleaning/ disinfection, from different sites (personal rooms, common areas) and across different settings (hospitals, cruise ship).	Low ***NOT PEER REVIEWED***	Not reported

Table 2: In-progress Syntheses

Title	Anticipated Release Date	Setting	Description of Document
Previously reported evidence			
Dalla Nora, V., Azevedo, N. & Rosa, D. (2020). *Survival of SARS-CoV-2 on different surfaces of the dental office and the effective disinfection agents. PROSPERO, CRD42020188152.*	Oct 15, 2020	Dental office	This systematic review aims to explore the survival time of SARS-CoV-2 on different surfaces in dental offices and determine decontamination agents and concentration levels for effective disinfection.
Deliga Schroder, A. G., Guariza Filho, O., Neto, J. S., Gonçalves, F. M., Bittencourt Basso, I., Sampaio Santos, R., … Nogueira Cortz Ravazzi, G. M. (2020). *COVID-19 survival time on inanimate surfaces: a systematic review. PROSPERO, CRD42020185643.*	Jun 30, 2020	Multiple	This systematic review aims to explore survival time of SARS-CoV-2 on different types of inanimate surfaces.

Table 3: Single Studies

Reference	Date Released	Study Design	Setting	Method of testing and timing	Summary of findings	Quality Rating:
Prevalence Studies						
New evidence reported March 5, 2021						
Ming, Z., Han, S., Deng, K., Ha, Y., Kim, S., Reyes, E., … Samadpour, M. (2020). Environmental monitoring shows SARS-CoV-2 contamination of surfaces in food plants. *Preprint.*	Dec 11, 2020	Prevalence	Surface samples collected from 116 food production facilities. USA	RT-PCR Samples were collected by plant personnel in different areas and on different surface types between Mar 17 and Sep 3, 2020. 5 facilities followed longitudinally for timeline data analyses in function of preventive measures (but no details provided on these measures). No information on cleaning protocols provided.	278/22,643 (1.23%) of samples tested positive for SARS-CoV-2, and 62/116 (53%) of facilities had at least 1 positive sample. Virus commonly found on frequently touched surfaces such as doorknobs/handles, tables, computer devices and sanitizer dispensers. Receiving rooms and entrance had the highest occurrence of positive samples. In 3/5 facilities, decreasing trend of daily positive rate observed.	Low ***PREPRINT***

Moreno, T., Pintó, R. M., Bosch, A., Moreno, N., Alastuey, A., Minguillón, M. C., ... Querol, X. (2021). Tracing surface and airborne SARS-CoV-2 RNA inside public buses and subway trains. *Environment International*, *147*, 106326. Epub ahead of print.	Dec 9, 2020	Prevalence	Surface and air samples collected from buses and subway trains. Spain	RT-PCR 75 samples from buses and 24 from trains samples collected between May and Jul 2020 (78 surface samples, 12 air samples, 9 samples from air-conditioning filters). Bus samples were collected before and other after cleaning (bleach or ozone); train samples were collected at the end of the day. 82 of the 99 samples were analysed.	30/82 were positive for SARS-CoV-2. Train: 6/15 surface samples positive 2/6 air samples positive 0/3 filters samples positive Bus: 13/30 surface samples positive; 3 of these 13 surfaces were still positive after cleaning 1/6 air samples positive 3/6 filters samples positive Most of the positive samples (24/30) tested positive for only 1 of the 3 RNA targets; risk of infections considered to be extremely low.	Moderate
Maestre, J. P., Jarma, D., Yu, C., Siegel, J., Horner, S., & Kinney, K. A. (2020). Distribution of SARS-CoV-2 RNA signal in a home with COVID-19 positive occupants. *Preprint.*	Dec 2, 2020	Prevalence	Surface and dust samples collected from a household with 2 confirmed COVID-19 cases 1 month after symptom resolution (2 months after symptom onset) USA	RT-PCR 22 surface samples collected by household member using a sampling kit provided by the research team. Dust samples collected from bedroom and HVAC filter using a handheld vacuum cleaner. Information on cleaning practices and surface material obtained by remote survey.	11/24 (46%) of surface samples were positive for SARS-CoV-2, mostly from the bedroom, surface of HVAC filter, and living room. Samples from surfaces regularly cleaned (e.g., vinyl floor of kitchen and bathroom, kitchen counter and dinner table) were mostly negative. Virus concentration in dust samples from the carpet floor in the bedroom were a least 1 order of magnitude higher than in dust samples from the HVAC filter.	Moderate ***PREPRINT***

Akter, S., Roy, P. C., Ferdaus, A., Ibnat, H., Rubayet Ul Alam, A. S. M., Nigar, S., … Anwar Hossain, M. (2020). Prevalence and stability of SARS CoV-2 RNA on Bangladeshi banknotes. *Preprint.*	Nov 30, 2020	Prevalence	Prevalence and stability of SARS-CoV-2 on banknotes in circulation. Bangladesh	RT-PCR Prevalence: 425 banknotes collected from 56 entities (shops, restaurants, drivers, etc.) over a period of 3 months in 2 Southern districts of Bangladesh. Stability: banknotes spiked with SARS-CoV-2 (234 samples).	31/425 (7.3%) of banknotes were positive for SARS-CoV-2. The entity with the highest prevalence of positive banknote was a local transport business (14.3%). Stability: N gene detected for up to 72 hours at 35°C. Survival higher on new banknotes compared to older banknotes. New banknotes: more fibrous and compact texture, and more absorbent than old ones.	High ***PREPRINT***
Liu, P., Yang, M., Zhao, X., Guo, Y., Wang, L., Zhang, J., … Wu, G. (2020). Cold-chain transportation in the frozen food industry may have caused a recurrence of COVID-19 cases in destination: Successful isolation of SARS-CoV-2 virus from the imported frozen cod package surface. *Biosafety and Health*, *2*(4), 199–201.	Nov 19, 2020	Prevalence	Surface samples collected from frozen cod outer packaging, as part of an outbreak investigation of 2 positive COVID-19 cases in workers loading/unloading frozen cod. China	Detection method not specified. 421 samples collected. Cleaning of surfaces unlikely prior to sample collection, although not explicitly stated.	50/421 (12%) of samples tested positive for SARS-CoV-2.	Low

Di Carlo, P., Chiacchiaretta, P., Sinjari, B., Aruffo, E., Stuppia, L., De Laurenzi, V., … Ucciferri, C. (2020). Air and surface measurements of SARS-CoV-2 inside a bus during normal operation. *PLoS ONE*, *15*(11), e0235943. Epub ahead of print.	Nov 5, 2020	Prevalence	Surface and air samples collected from buses. Italy	RT-PCR Samples were collected during the last week of lockdown and the first week after lockdown (May 2020). Air samples were collected every weekday for the length of the bus shift (6.5 hours) and surface samples were collected from 5 commonly touched surfaces (ticket machine and stop buttons) before and after the shift. Cleaning and sanitation performed daily.	None of the samples (surface and air) tested positive.	High
Harvey, A. P., Fuhrmeister, E. R., Cantrell, M., Pitol, A. K., Swarthout, J. M., Powers, J. E., … Pickering, A. J. (2020). Longitudinal monitoring of SARS-CoV-2 RNA on high-touch surfaces in a community setting. *Preprint.*	Nov 1, 2020	Prevalence	Surface samples from high-touch non-porous surfaces such as handles were collected from community settings. USA	RT-PCR 348 samples were collected from 33 unique surfaces (trash can, liquor store, bank, metro door, grocery store, crosswalk buttons, gas station/pump, restaurant, convenience store and post box), throughout a COVID-19 outbreak (Mar 13-Jun 23, 2020). Cleaning frequency/method at sampling locations were not monitored.	29/348 (8.3%) of surface samples were positive for SARS-CoV-2, with 17/33 (52%) of surfaces being positive at least once. The surfaces most frequently contaminated were a trash can handle and a liquor store door handle. The estimated risk of infection from touching a contaminated surface was low (less than 5 in 10,000)	High ***PREPRINT***

Hu, X., Ni, W., Wang, Z., Ma, G., Pan, B., Dong, L., ... Jiang, F. (2020). The distribution of SARS-CoV-2 contamination on the environmental surfaces during incubation period of covid-19 patients. *Ecotoxicology and environmental safety*, 208, 111438.	Oct 12, 2020	Prevalence	Hotel 3 rooms of quarantined overseas students returned from America who had tested positive for COVID-19 (2 symptomatic and 1 pre-symptomatic) China	RT-PCR Surface samples (light switch, bathroom door knob, toilet, sink, sewer inlet, floor near bed, bedside table, bedding, TV and remote control, telephone and bay window) from within each room were collected within 4 hours of the students testing positive for COVID-19. No disinfectant was used during the hotel quarantine.	Overall, 14 of 41 (34.1%) samples tested positive. 46% and 62% of samples from the symptomatic student's rooms tested positive, whereas no samples from the pre-symptomatic student tested positive. All positive samples were from bathroom and bedroom sites (none from living room). The % of positive samples across different surfaces were cotton 60%, ceramic 40%, metal 40%, wood 33% and plastic 16.7%.	Low
Luo, L., Liu, D., Zhang, H., Li, Z., Zhen, R., Zhang, X., ... Mao, C. (2020). Air and surface contamination in non-health care settings among 641 environmental specimens of 39 COVID-19 cases. *PLoS Neglected Tropical Diseases*, 14(10), e0008570.	Oct 9, 2020	Prevalence	Surface samples from sites in which persons with confirmed COVID-19 (9 asymptomatic and 30 symptomatic COVID-19 cases) resided or visited (home or hotel) China	RT-PCR Samples were taken from high touch surfaces and toilets within 3 days of a positive test.	One or more positive surface sample was identified for 9 of the 39 positive cases. Most were within the home or hotel room, particularly within the bathroom (most positive samples being from the floor drain and toilet bowl). No positive samples were found in public areas.	Low

Parker, C. W., Singh, N., Tighe, S., Blachowicz, A., Wood, J. M., Seuylemezian, A., … Venkateswaran, K. (2020). End-to-end protocol for the detection of SARS-CoV-2 from built environments. *mSystems*, *5*(5), e00771-20.	Oct 6, 2020	Prevalence	Not explicitly stated but from the authors contributions it may be buildings at the NASA Jet Propulsion Laboratory, California Institute of Technology. USA	RT-PCR Environmental samples were collected from 7 different materials found across 10 buildings, in areas with large amounts of pedestrian traffic and deemed high-touch surfaces (stainless steel, Amerstat, plastic, copper, and painted surfaces). Implemented safety practices in the buildings included cleaning, social distancing and mask use.	None of the 368 samples collected tested positive for SARS-CoV-2.	Low
Fernández-de-Mera, I. G., Rodriguez Del-Rio, F. J., de la Fuente, J., Perez-Sancho, M., Hervas, D., Moreno, I., … Gortazar, C. (2020). Detection of environmental SARS-CoV-2 RNA in a high prevalence setting in Spain. *Transboundary and Emerging Diseases*. Epub ahead of print.	Sep 7, 2020	Prevalence	Surface samples from public service sites in a rural village with ageing population. Household samples (clothing and surfaces) of active and recovered COVID-19 symptomatic cases. Spain	RT-PCR Samples were collected after case numbers had dropped to only 3 active cases in the village at first sampling and none at second sampling (16 days later). Hand and household disinfection were encouraged. Hypochlorite disinfection of public spaces occurred 1-3 times weekly prior/during sampling.	2 of the 6 public service sites surfaces tested positive, the petrol station and the pharmacy. Clothing in both active case households and a surface from 1 of the 6 recovered households tested positive. During repeat sampling clothing from 1 of 7 recovered households tested positive.	Moderate

Piana, A., Colucci, M. E., Valeriani, F., Marcolongo, A., Sotgiu, G., Pasquarella, C., … Romano Spica, V. (2021). Monitoring COVID-19 transmission risks by RT-PCR tracing of droplets in hospital and living environments. *Preprint.*	Aug 25, 2021	Prevalence	Public buildings (office, fast food outlet, church), outdoor surfaces (handles, handrails, playgrounds) and used handkerchiefs. Italy	RT-PCR Surface samples were collected after the epidemic peak. No information on cleaning protocols of public surfaces.	25 samples from within public buildings (toilets, church pews, floors, wall tiles, phone, computer keyboards, air circulation system) and 16 outdoor samples (handrail, shared scooter grip, bus stop bench, coffee dispenser button, door handle, playground). No SARS-CoV-2 RNA was detectable on any surface sample, although presence of biological fluids were detected.	Moderate ***PREPRINT***
Mouchtouri, V. A., Koureas, M., Kyritsi, M., Vontas, A., ros, Kourentis, L., … Hadjichristodoulou, C. (2020). Environmental contamination of SARS-CoV-2 on surfaces, air-conditioner and ventilation systems. *International Journal of Hygiene and Environmental Health*, 230, 113599.	Aug 13, 2020	Prevalence	International ferry boat and nursing home after a COVID-19 outbreak had been identified. Greece	RT-PCR Surface samples were collected once an outbreak was identified and before application of cleaning and disinfection measures.	5 of 9 surface swabs from the ferry boat tested positive (hand contact points such as flour scoop handle, doorknob, bar counter and light switch). 4 of 20 surface swabs from the nursing home tested positive (such as patient bed side rail).	Moderate
Xie, C., Zhao, H., Li, K., Zhang, Z., Lu, X., Peng, H., … Lu, J. (2020). The evidence of indirect transmission of SARS-CoV-2 reported in Guangzhou, China. *BMC Public Health*, *20*(1), 1202-1202.	Aug 5, 2020	Prevalence	1 residential building where 2 family clusters of confirmed COVID-19 cases resided. China	RT-PCR 21 surface samples from the elevator and houses of 2 families. Before sampling the interior of the elevator had been disinfected several times.	1 of 24 samples tested positive (door handle of first infected family residence) and none of 10 samples tested positive during first and second sampling respectively. It was believed transmission occurred from one family to another via a contaminated elevator button (13 days prior to surface testing).	Low

Jiang, F. C., Jiang, X. L., Wang, Z. G., Meng, Z. H., Shao, S. F., Anderson, B. D., & Ma, M. J. (2020). Detection of severe acute respiratory syndrome coronavirus 2 RNA on surfaces in quarantine rooms. *Emerging Infectious Diseases*, *26*(9), 2162–2164.	May 18, 2020	Prevalence	Hotel Surface samples collected from 2 rooms in which 2 pre-symptomatic patients had stayed for < 24 hours. China	RT-PCR 11 samples collected on the same surfaces in each room on Mar 20 and 22, 2020. Cleaning of surfaces prior to sample collection unlikely, although not explicitly stated.	8/22 (36%) of samples were positive for SARS-CoV-2 (55% in 1 room, 18% in the other room). Pillow cover was the only sample positive in both rooms. Duvet cover, sheet, towel, bathroom door handle and light switch were positive in 1 room; faucet was positive in the other room. The other samples (including door handle, toilets and TV remotes) were negative in both rooms.	High
Previously reported evidence						
Wong, J.C.C., Hapuarachichi, H.C., Arivalan, S., Tien, W.P., Koo, C., Mailepessov, D., … Ng, L.C. (2020). Environmental contamination of SARS-CoV-2 in a non-healthcare setting. *International Journal of Environmental Research & Public Health, 18*(1), 117.	Dec 26, 2020	Prevalence	Sites in which persons with confirmed COVID-19 resided or visited. Singapore	RT-PCR Samples collected before and after disinfection of high touch areas (rooms, toilets, elevators) 1-3 days after occupancy. Cleaning and disinfection conducted by professional cleaning companies using various agents.	Two of 428 (0.5%) samples tested positive originating from a bedside wall and bed handle prior to disinfection. Following disinfection and cleaning, repeated collected samples tested negative.	Moderate

Abrahão, J. S., Sacchetto, L., Rezende, I. M., Rodrigues, R. A. L., Crispim, A. P. C., Moura, C., ... Drumond, B. P. (2020). Detection of SARS-CoV-2 RNA on public surfaces in a densely populated urban area of brazil: A potential tool for monitoring the circulation of infected patients. *The Science of the Total Environment*, 142645. Epub ahead of print.	Oct 1, 2020	Prevalence	Public places (near hospital and public transportation areas) in region with highest number of reported COVID-19 cases. Brazil	RT-PCR No information on cleaning protocols of public surfaces.	16 of 101 (16.8%) samples tested positive. Positive samples were found on metal and concrete surfaces at hospital bus stations (bench, ground), hospital sidewalks, bus terminals (handrails), and public square seating (table and benches).	High
Marshall, D., Bois, F., Jensen, S. K. S., Linde, S. A., Higby, R., Remy-McCort, Y., ... Martin, G.G. (2020). Sentinel coronavirus environmental monitoring can contribute to detecting asymptomatic SARS-CoV-2 virus spreaders and can verify effectiveness of workplace COVID-19 controls. *Microbial Risk Analysis*. Epub ahead of print.	Aug 30, 2020	Prevalence	Workplace 9 office and mixed-used industrial locations. Europe USA	RT-PCR Samples were collected near end of work shifts and prior to disinfection and cleaning.	Number or percent of positive samples not reported. Workplaces with positive samples were more likely to have employees with confirmed cases of COVID-19. Highest positive sample rates were found among door handles and shared furniture (break room chairs, workbenches).	Moderate

Yamagishi, T., Ohnishi, M., Matsunaga, N., Kakimoto, K., Kamiya, H., Okamoto, K., … Wakita, T. (2020). Environmental sampling for severe acute respiratory syndrome coronavirus 2 during COVID-19 outbreak in the Diamond Princess cruise ship. *The Journal of Infectious Diseases*, *222*(7), 1098-1102.	Jul 21, 2020	Prevalence	Cruise ship Surface samples from vacant cabins of those with confirmed COVID-19 cases, cabins with no confirmed cases, and common areas.	Reverse transcription polymerase chain reaction (RT-PCR) used to detect presence of SARS-CoV-2 RNA. Samples collected 7-9 days after disinfection with 5% hydrogen peroxide.	No viable virus was detected in any of the samples. 58 of 601 (10%) samples tested positive from cabins with confirmed COVID-19 cases 1-17 days after the cabins were vacated, but not from non-case-cabins. The virus was most often detected on the bathroom floor near the toilet and bed pillows.	High
Döhla, M., Wilbring, G., Schulte, B., Kümmerer, B.M., Diegmann, C., Sib, E., … Schmithausen, R.M. (2020). SARS-CoV-2 in environmental samples of quarantined households. *Preprint.*	Jun 2, 2020	Prevalence	Households under quarantine with at least one confirmed COVID-19 case. Germany	RT-PCR Viral culture test Surface samples collected from frequently shared objects (e.g., door handles, remote control).	4 of 119 (3.36%) samples tested positive. Positive samples were found on electronic devices, knobs/handles, and furniture. Viral culturing detected no viable virus from the samples.	Moderate ***PREPRINT***
Bloise, I., Gómez-Arroyo, B., & García-Rodríguez, J. (2020). Detection of SARS-CoV-2 on high-touch surfaces in a clinical microbiology laboratory. *The Journal of Hospital Infection*, *105*(4), 784-786.	May 15, 2020	Prevalence	Clinical microbiology laboratory with high density of samples tested for COVID-19. Samples from high touch surfaces. Spain	RT-PCR Cleaning and disinfection protocols not reported.	4 of 22 (18%) samples tested positive. Positive samples were found on commonly used objects, such as keyboards, telephones and computer mouse, representing potential sources of infection for laboratory personnel.	Moderate

Lee, S.E., Lee, D.Y., Lee, W.G., Kang, B., Jang, Y.S., Ryu, B., … Lee, E. (2020). Detection of novel coronavirus on the surface of environmental materials contaminated by COVID-19 patients in the Republic of Korea. *Osong Public Health and Research Perspectives*, *11*(3), 128–132.	May 8, 2020	Prevalence	A rehabilitation centre and an apartment building complex with COVID-19 outbreaks. Korea	RT-PCR Samples collected from high touch surfaces (e.g. door handles).	2 of 12 (16.7%) samples from communal facilities where disinfection and cleaning had not been conducted prior to collection tested positive. Both samples were from a door handle of a COVID-19 positive patient's room.	Moderate
Laboratory Studies						
New evidence reported March 5, 2021						
Morris, D., Yinda, K. C., Gamble, A., Rossine, F. W., Huang, Q., Bushmaker, T., … Lloyd-Smith, J.O. (2020). Mechanistic theory predicts the effects of temperature and humidity on inactivation of SARS-CoV-2 and other enveloped viruses. *Preprint*.	Nov 13, 2020	Laboratory	SARS-CoV-2 suspension deposited onto polypropylene plastic surface at different temperatures and humidities. USA	Viral culture test	Viral decay was faster with increasing temperature with decay at 27°C 5-10 X faster than decay at 10°C. Virus decay was fastest at 65% relative humidity and tended to be slower at lower (40%) or higher (85%) relative humidities.	Not appraised ***PREPRINT***

Harbourt, D. E., Haddow, A. D., Piper, A. E., Bloomfield, H., Kearney, B. J., Fetterer, D., … Minogue, T. (2020). Modeling the stability of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) on skin, currency, and clothing. *PLoS Neglected Tropical Diseases, 14*(11), e0008831. Epub ahead of print.	Nov 9, 2020	Laboratory	Evaluated surface stability of SARS-CoV-2 on swine skin, banknotes and scrub fabric at different temperatures. USA	Viral culture test	SARS-CoV-2 remained stable in swine skin for the full experiment of 14 days at 4°C; 96 hours at 22°C and up to 8 hours at 37°C. At 4°C, SARS-CoV-2 remained quantifiable on bank notes and clothing for up to 96 hours. At 22°C, SARS-CoV-2 decay was quicker, being negative after 24 hours on bank notes and 8 hours on clothing. At 37°C SARS-CoV-2 was not detected after 4 hours on clothing and 8 hours on bank notes.	Not appraised
Magurano, F., Baggieri, M., Marchi, A., Rezza, G., & Nicoletti, L. (2020). SARS-CoV-2 infection: the environmental endurance of the virus can be influenced by the increase of temperature. *Clinical Microbiology and Infection.* Epub ahead of print.	Nov 5, 2020	Laboratory	SARS-CoV-2 suspension deposited onto polypropylene plastic at different temperatures and harvested at different predefined time-points (up to 7 days) at a relative humidity of 35-45%. Italy	Viral culture test	At 20-25°C, virus infectivity on a plastic surface reduced rapidly in the first 24-36 hours. At 28°C, same reduction was observed in the first 8-12 hours. At both 20-25°C and at 28°C, SARS-CoV-2 maintain its ability to infect cells on a plastic surface for up to 84 hours but was not detectable at 96 hours.	Not appraised

Riddell, S., Goldie, S., Hill, A., Eagles, D., & Drew, T.W. (2020). The effect of temperature on persistence of SARS-CoV-2 on common surfaces. *Virology Journal (17)*, 145.	Oct 7, 2020	Laboratory	SARS-CoV-2 suspension dried onto glass, stainless steel, paper and polymer bank notes, vinyl, cloth in the dark for up to 28 days at 20°C, 30°C and 40°C and 50% humidity. Australia	Viral culture test	Infectious virus was still detectable after 28 days at 20°C, for all non-porous surfaces tested. For porous (cloth) no infectious virus was detected past day 14, with the majority absorbed soon after application. At 30°C infectious virus was detectable for 7 days for most non-porous surfaces and 3 days for cloth. At 40°C infectious virus was not recovered past 48 hours for non-porous and 24 hours for cloth.	Not appraised
Matson, M.J., Yinda, C.K., Seifert, S.N., Bushmaker, T., Fischer, R.J., van Doremalen, N., … Munster, J.J. (2020). Effect of environmental conditions on SARS-CoV-2 stability in human nasal mucus and sputum. *Emerging Infectious Diseases, 26*(9), 2276-2278.	Jun 8, 2020	Laboratory	SARS-CoV-2 mixed with commercially available nasal mucus and sputum and deposited on polypropylene discs at different temperatures and humidities. USA	Viral culture test and RT-PCR	In surface nasal mucus, half-life of SARS-CoV-2 was shorter at 27°C/85%RH than 21°C/40%RH (p=0.002) and 4°C/40%RH (p=0.0007). Half-life was shorter on the surface compared to in liquid nasal mucus (p=0.01). In surface sputum, half-life of SARS-CoV-2 was shorter at 27°C/85%RH (p=0.0002) and 21°C/40%RH (p=0.004) compared with 4°C/40%RH, with no difference in half-life between liquid and surface sputum. Infectious virus persisted in both nasal mucus and sputum on surfaces for ~24 hours and SARS-CoV-2 RNA remained detectable for ≥7 days in all surface samples.	Not appraised

Kratze, A., Steiner, S., Todt, D., V'kovski, P., Brueggemann, Y., Steinmann, J. … Pfaender, S. (2020). Temperature-dependent surface stability of SARS-CoV-2. *Journal of Infection 81*(3), 452-482.	Jun 2, 2020	Laboratory	SARS-CoV-2 suspensions dried onto metal discs at 4°C, RT and 30°C for up to 9 days at 30-40% humidity. Germany	Viral culture test	Drying reduced infectivity of virus by 100-fold, but then remained stable for 4-8 hours. Beyond 8 hours there was a stable, slow decline of viral titres at all temperatures over several days. Detectable infectious virus was still present after 180 hours. The median half-life is predicted to be 9.1 hours at RT, 12.9 hours at 4°C, and 17.9 hours at 30°. Surface stability may be due to constant humidity.	Not appraised
Chin, A. W. H., Chu, J. T. S., Perera, M. R. A., Hui, K. P. Y., Yen, H.-L., Chan, M. C. W., . . . Poon, L. L. M. (2020). Stability of SARS-CoV-2 in different environmental conditions. *The Lancet*. Microbe, 1(1), e10. Epub ahead of print.	Apr 2, 2020	Laboratory	SARS-CoV-2 added to a surface (printing and tissue paper, treated wood, cloth, glass, banknote, stainless steel, plastic, surgical mask) at different temperatures and pHs and added to various disinfectants for up to 14 days. China	Viral culture test	After 3 hours, no infectious virus could be recovered from printing and tissue paper, after 2 days on treated wood and cloth, 4 days on glass and banknote or 7 days on stainless steel or plastic. A detectable level of infectious virus was present on the outer layer of a surgical mask on day 7. SARS-CoV-2 is extremely stable in a wide range of pH values at room temperature. It is highly stable at 4°C, but at 70°C the time for virus inactivation was reduced to 5 mins. Except for hand soap, no infectious virus could be detected after a 5-minute incubation at room temperature.	Not appraised

Previously reported evidence						
Liu, Y., Li, T., Deng, Y., Liu, S., Zhang, D., Li, H., … Li, J. (2020). Stability of SARS-CoV-2 on environmental surfaces and in human excreta. *The Journal of Hospital Infection*. Epub ahead of print.	Oct 30, 2020	Laboratory	Steel, plastic, glass, ceramics, paper, cotton, wood, latex gloves, surgical mask deposited and left for 7 days. China	Viral culture test	The virus remained stable and viable for seven days on surfaces of plastic, stainless steel, glass, ceramics, wood, latex gloves and surgical mask. The virus did not remain infectious after 4 days on cotton clothes and after 5 days on paper. In both of these materials, rapid loss of virus infectivity was observed within 1 hour after incubation. Across most of the tested conditions, in the initial phase of viral decay, loss of infectivity was rapid, whereas in the terminal phase, viral infectivity decreased slowly.	Not appraised
Pelisser, M., Thompson, J., Majra, D., Youhanna, S., Stebbing, J., & Davies, P. (2020). Sports balls as potential SARS-CoV-2 transmission vectors. *Public Health in Practice 1*, 100029. Epub ahead of print.	Jul 10, 2020	Laboratory	Sports equipment with inactivated virus pipetted directly onto the surface in a lab UK	Testing protocol not reported	Surfaces of sports balls were tested before and after disinfection, and after use on a grass field. All samples tested negative. The authors note a limitation to the study may have been the method used to transfer the virus to surfaces using polyester swabs which may not have been effective.	Not appraised

Pastorino, B., Touret, F., Gilles, M., de Lamballerie, X., & Charrel, R.N. (2020). Prolonged infectivity of SARS-CoV-2 in fomites. *Emerging Infectious Diseases*. 26(9), 2256-2257.	Jun 24, 2020	Laboratory	SARS-CoV-2 deposited on polystyrene plastic, aluminum, and glass for 96 hours France	Viral culture test	SARS-CoV-2 demonstrated viral stability for 96 hours on all tested surfaces. Protein mediums increased SARS-CoV-2 infectivity, suggesting that protein-rich mediums such as airway secretions can protect the expelled virus, potentially enhancing persistence and transmission via contaminated surfaces.	Not appraised

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