COVID-19 – environmental contamination, viral viability on surfaces


Middle Eastern respiratory syndrome, an emerging viral infection with a global case fatality rate of 35.5%, caused major outbreaks first in 2012 and 2015, though new cases are continuously reported around the world. Transmission is believed to mainly occur in healthcare settings through aerosolized particles. This study uses Quantitative Microbial Risk Assessment to develop a generalizable model that can assist with interpreting reported outbreak data or predict risk of infection with or without the recommended strategies. The exposure scenario includes a single index patient emitting virus-containing aerosols into the air by coughing, leading to short- and long-range airborne exposures for other patients in the same room, nurses, healthcare workers, and family visitors. Aerosol transport modeling was coupled with Monte Carlo simulation to evaluate the risk of MERS illness for the exposed population. Results from a typical scenario show the daily mean risk of infection to be the highest for the nurses and healthcare workers (8.49 × 10(-4) and 7.91 × 10(-4) , respectively), and the lowest for family visitors and patients staying in the same room (3.12 × 10(-4) and 1.29 × 10(-4) , respectively). Sensitivity analysis indicates that more than 90% of the uncertainty in the risk characterization is due to the viral concentration in saliva. Assessment of risk interventions showed that respiratory masks were found to have a greater effect in reducing the risks for all the groups evaluated (>90% risk reduction), while increasing the air exchange was effective for the other patients in the same room only (up to 58% risk reduction).


Cai J, Sun W, Huang J, Gamber M, Wu J, He G.


To determine possible modes of virus transmission, we investigated a cluster of COVID-19 cases associated with a shopping mall in Wenzhou, China. Data indicated that indirect transmission of the causative virus occurred, perhaps resulting from virus contamination of common objects, virus aerosolization in a confined space, or spread from asymptomatic infected persons.


Stability of SARS-CoV-2 in different environmental conditions.  
Competing Interest Statement  
The authors have declared no competing interest.  
Funding Statement  
This work was supported by NIADI, NIH (USA) (contract HHSN272201400006C).  
Author Declarations  
All relevant ethical guidelines have been followed; any necessary IRB and/or ethics committee approvals have been obtained and details of the IRB/oversight body are included in the manuscript.  
Yes  
All necessary patient/participant consent has been obtained and the appropriate institutional forms have been archived.  
Yes  
I understand that all clinical trials and any other prospective interventional studies must be registered with an ICMJE-approved registry, such as ClinicalTrials.gov. I confirm that any such study reported in the manuscript has been registered and the trial registration ID is provided (note: if posting a prospective study registered retrospectively, please provide a statement in the trial ID field explaining why the study was not registered in advance).  
Yes  
I have followed all appropriate research reporting guidelines and uploaded the relevant EQUATOR Network research reporting checklist(s) and other pertinent material as supplementary files, if applicable.  
Yes  
All data will be available upon request.  
[https://www.medrxiv.org/content/medrxiv/early/2020/03/18/2020.03.15.20036673.full.pdf](https://www.medrxiv.org/content/medrxiv/early/2020/03/18/2020.03.15.20036673.full.pdf)


With the rapid spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) that results in coronavirus disease 2019 (COVID-19), corporate entities, federal, state, county and city governments, universities, school districts, places of worship, prisons, health care facilities, assisted living organizations, daycares, homeowners, and other building owners and occupants have an opportunity to reduce the potential for transmission through built environment (BE) mediated pathways. Over the last decade, substantial research into the presence, abundance, diversity, function, and transmission of microbes in the BE has taken place and revealed common pathogen exchange pathways and mechanisms. In this paper, we synthesize this microbiology of the BE research and the known information about SARS-CoV-2 to provide actionable and achievable guidance to BE decision makers, building operators, and all indoor occupants attempting to minimize infectious disease transmission through environmentally mediated pathways. We believe this information is useful to corporate and public administrators and individuals responsible for building operations and environmental services in their decision-making process about the degree and duration of social-distancing measures during viral epidemics and pandemics.  
[https://www.preprints.org/manuscript/202003.0197/v2](https://www.preprints.org/manuscript/202003.0197/v2)
Geller C, Varbanov M, Duval RE.

**Human coronaviruses: insights into environmental resistance and its influence on the development of new antiseptic strategies.**


The Coronaviridae family, an enveloped RNA virus family, and, more particularly, human coronaviruses (HCoV), were historically known to be responsible for a large portion of common colds and other upper respiratory tract infections. HCoV are now known to be involved in more serious respiratory diseases, i.e. bronchitis, bronchiolitis or pneumonia, especially in young children and neonates, elderly people and immunosuppressed patients. They have also been involved in nosocomial viral infections. In 2002-2003, the outbreak of severe acute respiratory syndrome (SARS), due to a newly discovered coronavirus, the SARS-associated coronavirus (SARS-CoV); led to a new awareness of the medical importance of the Coronaviridae family. This pathogen, responsible for an emerging disease in humans, with high risk of fatal outcome; underline the pressing need for new approaches to the management of the infection, and primarily to its prevention. Another interesting feature of coronaviruses is their potential environmental resistance, despite the accepted fragility of enveloped viruses. Indeed, several studies have described the ability of HCoVs (i.e. HCoV 229E, HCoV OC43 (also known as betacoronavirus 1), NL63, HKU1 or SARS-CoV) to survive in different environmental conditions (e.g. temperature and humidity), on different supports found in hospital settings such as aluminum, sterile sponges or latex surgical gloves or in biological fluids. Finally, taking into account the persisting lack of specific antiviral treatments (there is, in fact, no specific treatment available to fight coronaviruses infections), the Coronaviridae specificities (i.e. pathogenicity, potential environmental resistance) make them a challenging model for the development of efficient means of prevention, as an adapted antisepsis-disinfection, to prevent the environmental spread of such infective agents. This review will summarize current knowledge on the capacity of human coronaviruses to survive in the environment and the efficacy of well-known antiseptic-disinfectants against them, with particular focus on the development of new methodologies to evaluate the activity of new antiseptic-disinfectants on viruses.


Hasan S, Hossain MM.

**Analysis of COVID-19 M Protein for Possible Clues Regarding Virion Stability, Longevity and Spreading.**

*OSF Preprints.* March. 2020;15.

The Severe Acute Respiratory Syndrome Coronavirus 2 or COVID-19 has been the cause of a global pandemic in 2020. With the numbers infected rising well above a 100,000 and confirmed deaths above 4000, it has become the paramount health concern for the global community at present. The COVID-19 genome has since been sequenced and its predicted proteome identified. In this study, we looked at the expected COVID-19 proteins and compare them to its close relative, the Severe Acute Respiratory Syndrome-Related Coronavirus. In particular we focussed on the M protein which is known to play a significant role in the virion structure of Coronaviruses. The rationale here was that since the major risk factor associated with COVID-19 was its ease of spread, we wished to focus on the viral
structure and architecture to look for clues that may indicate structural stability, thus prolonging the time span for which it can survive free of a host. As a result of the study, we found some rather interesting differences between the M protein for COVID-19 and the SARS-CoV virus M protein. This included amino acid changes from non-polar to polar residues in regions important for anchoring the protein in the envelope membrane.

https://osf.io/e7jkc/download


Currently, the emergence of a novel human coronavirus, SARS-CoV-2, has become a global health concern causing severe respiratory tract infections in humans. Human-to-human transmissions have been described with incubation times between 2-10 days, facilitating its spread via droplets, contaminated hands or surfaces. We therefore reviewed the literature on all available information about the persistence of human and veterinary coronaviruses on inanimate surfaces as well as inactivation strategies with biocidal agents used for chemical disinfection, e.g. in healthcare facilities. The analysis of 22 studies reveals that human coronaviruses such as Severe Acute Respiratory Syndrome (SARS) coronavirus, Middle East Respiratory Syndrome (MERS) coronavirus or endemic human coronaviruses (HCoV) can persist on inanimate surfaces like metal, glass or plastic for up to 9 days, but can be efficiently inactivated by surface disinfection procedures with 62-71% ethanol, 0.5% hydrogen peroxide or 0.1% sodium hypochlorite within 1 minute. Other biocidal agents such as 0.05-0.2% benzalkonium chloride or 0.02% chlorhexidine digluconate are less effective. As no specific therapies are available for SARS-CoV-2, early containment and prevention of further spread will be crucial to stop the ongoing outbreak and to control this novel infectious thread.


The recent emergence of Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) causing COVID-19 is a major burden for health care systems worldwide. It is important to address if the current infection control instructions based on active ingredients are sufficient. We therefore determined the virucidal activity of two alcohol-based hand rub solutions for hand disinfection recommended by the World Health Organization (WHO), as well as commercially available alcohols. Efficient SARS-CoV-2 inactivation was demonstrated for all tested alcohol-based disinfectants. These findings show the successful inactivation of SARS-CoV-2 for the first time and provide confidence in its use for the control of COVID-19.Importance The current COVID-19 outbreak puts a huge burden on the world’s health care systems. Without effective therapeutics or vaccines being available, effective hygiene measure are of utmost importance to prevent viral spreading. It is therefore crucial to evaluate current infection control strategies against SARS-CoV-2. We show the
inactivation of the novel coronavirus for the first time and endorse the importance of disinfectant-based hand hygiene to reduce SARS-CoV-2 transmission.

https://www.biorxiv.org/content/biorxiv/early/2020/03/17/2020.03.10.986711.full.pdf


**Aerodynamic Characteristics and RNA Concentration of SARS-CoV-2 Aerosol in Wuhan Hospitals during COVID-19 Outbreak.**

*biorxiv. 2020:2020.03.08.982637.*

Background The ongoing outbreak of COVID-19 has spread rapidly and sparked global concern. While the transmission of SARS-CoV-2 through human respiratory droplets and contact with infected persons is clear, the aerosol transmission of SARS-CoV-2 has been little studied.

Methods Thirty-five aerosol samples of three different types (total suspended particle, size segregated and deposition aerosol) were collected in Patient Areas (PAA) and Medical Staff Areas (MSA) of Renmin Hospital of Wuhan University (Renmin) and Wuchang Fangcang Field Hospital (Fangcang), and Public Areas (PUA) in Wuhan, China during COVID-19 outbreak. A robust droplet digital polymerase chain reaction (ddPCR) method was employed to quantitate the viral SARS-CoV-2 RNA genome and determine aerosol RNA concentration.

Results The ICU, CCU and general patient rooms inside Renmin, patient hall inside Fangcang had undetectable or low airborne SARS-CoV-2 concentration but deposition samples inside ICU and air sample in Fangcang patient toilet tested positive. The airborne SARS-CoV-2 in Fangcang MSA had bimodal distribution with higher concentration than those in Renmin during the outbreak but turned negative after patients number reduced and rigorous sanitization implemented. PUA had undetectable airborne SARS-CoV-2 concentration but obviously increased with accumulating crowd flow.

Conclusions Room ventilation, open space, proper use and disinfection of toilet can effectively limit aerosol transmission of SARS-CoV-2. Gathering of crowds with asymptomatic carriers is a potential source of airborne SARS-CoV-2. The virus aerosol deposition on protective apparel or floor surface and their subsequent resuspension is a potential transmission pathway and effective sanitization is critical in minimizing aerosol transmission of SARS-CoV-2.

https://www.biorxiv.org/content/biorxiv/early/2020/03/10/2020.03.08.982637.full.pdf

Ong SWX, Tan YK, Chia PY, Lee TH, Ng OT, Wong MSY, et al.

**Air, Surface Environmental, and Personal Protective Equipment Contamination by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) From a Symptomatic Patient.**

*Jama. 2020.*

This study documents results of SARS-CoV-2 polymerase chain reaction (PCR) testing of environmental surfaces and personal protective equipment surrounding 3 COVID-19 patients in isolation rooms in a Singapore hospital.


Otter JA, Donskey C, Yezli S, Douthwaite S, Goldenberg SD, Weber DJ.

**Transmission of SARS and MERS coronaviruses and influenza virus in healthcare settings: the possible role of dry surface contamination.**
Viruses with pandemic potential including H1N1, H5N1, and H5N7 influenza viruses, and severe acute respiratory syndrome (SARS)/Middle East respiratory syndrome (MERS) coronaviruses (CoV) have emerged in recent years. SARS-CoV, MERS-CoV, and influenza virus can survive on surfaces for extended periods, sometimes up to months. Factors influencing the survival of these viruses on surfaces include: strain variation, titre, surface type, suspending medium, mode of deposition, temperature and relative humidity, and the method used to determine the viability of the virus. Environmental sampling has identified contamination in field-settings with SARS-CoV and influenza virus, although the frequent use of molecular detection methods may not necessarily represent the presence of viable virus. The importance of indirect contact transmission (involving contamination of inanimate surfaces) is uncertain compared with other transmission routes, principally direct contact transmission (independent of surface contamination), droplet, and airborne routes. However, influenza virus and SARS-CoV may be shed into the environment and be transferred from environmental surfaces to hands of patients and healthcare providers. Emerging data suggest that MERS-CoV also shares these properties. Once contaminated from the environment, hands can then initiate self-inoculation of mucous membranes of the nose, eyes or mouth. Mathematical and animal models, and intervention studies suggest that contact transmission is the most important route in some scenarios. Infection prevention and control implications include the need for hand hygiene and personal protective equipment to minimize self-contamination and to protect against inoculation of mucosal surfaces and the respiratory tract, and enhanced surface cleaning and disinfection in healthcare settings.


A novel human coronavirus, now named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2, referred to as HCoV-19 here) that emerged in Wuhan, China in late 2019 is now causing a pandemic. Here, we analyze the aerosol and surface stability of HCoV-19 and compare it with SARS-CoV-1, the most closely related human coronavirus. We evaluated the stability of HCoV-19 and SARS-CoV-1 in aerosols and on different surfaces and estimated their decay rates using a Bayesian regression model Competing Interest Statement The authors have declared no competing interest. Funding Statement This research was supported by the Intramural Research Program of the National Institute of Allergy and Infectious Diseases (NIAID), National Institutes of Health (NIH). JOL-S and AG were supported by the Defense Advanced Research Projects Agency DARPA PREEMPT # D18AC00031, and JOL-S was supported by the U.S. National Science Foundation (DEB-1557022) and the Strategic Environmental Research and Development Program (SERDP, RC-2635) of the U.S. Department of Defense. Author Declarations All relevant ethical guidelines have been followed; any necessary IRB and/or ethics committee approvals have been obtained and details of the IRB/oversight body are included in the manuscript. Yes All necessary patient/participant consent has been obtained and the appropriate institutional forms have been archived. Yes I understand that all clinical trials and any other prospective interventional studies must be registered with an ICMJE-approved registry, such as ClinicalTrials.gov. I confirm that any such study reported in the manuscript has been registered and the trial registration ID is provided (note: if posting a prospective study registered retrospectively, please provide a statement in the trial ID field explaining why the study was not registered in advance). Yes I have followed all appropriate research reporting guidelines and uploaded the relevant EQUATOR Network research reporting checklist(s) and other pertinent material as supplementary files, if applicable. Yes data is available upon request. https://www.medrxiv.org/content/medrxiv/early/2020/03/13/2020.03.09.20033217.full.pdf


The evolution of new and reemerging historic virulent strains of respiratory viruses from animal reservoirs is a significant threat to human health. Inefficient human-to-human transmission of zoonotic strains may initially limit the spread of transmission, but an
infection may be contracted by touching contaminated surfaces. Enveloped viruses are often susceptible to environmental stresses, but the human coronaviruses responsible for severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS) have recently caused increasing concern of contact transmission during outbreaks. We report here that pathogenic human coronavirus 229E remained infectious in a human lung cell culture model following at least 5 days of persistence on a range of common nonbiocidal surface materials, including polytetrafluoroethylene (Teflon; PTFE), polyvinyl chloride (PVC), ceramic tiles, glass, silicone rubber, and stainless steel. We have shown previously that noroviruses are destroyed on copper alloy surfaces. In this new study, human coronavirus 229E was rapidly inactivated on a range of copper alloys (within a few minutes for simulated fingertip contamination) and Cu/Zn brasses were very effective at lower copper concentration. Exposure to copper destroyed the viral genomes and irreversibly affected virus morphology, including disintegration of envelope and dispersal of surface spikes. Cu(I) and Cu(II) moieties were responsible for the inactivation, which was enhanced by reactive oxygen species generation on alloy surfaces, resulting in even faster inactivation than was seen with nonenveloped viruses on copper. Consequently, copper alloy surfaces could be employed in communal areas and at any mass gatherings to help reduce transmission of respiratory viruses from contaminated surfaces and protect the public health. IMPORTANCE: Respiratory viruses are responsible for more deaths globally than any other infectious agent. Animal coronaviruses that "host jump" to humans result in severe infections with high mortality, such as severe acute respiratory syndrome (SARS) and, more recently, Middle East respiratory syndrome (MERS). We show here that a closely related human coronavirus, 229E, which causes upper respiratory tract infection in healthy individuals and serious disease in patients with comorbidities, remained infectious on surface materials common to public and domestic areas for several days. The low infectious dose means that this is a significant infection risk to anyone touching a contaminated surface. However, rapid inactivation, irreversible destruction of viral RNA, and massive structural damage were observed in coronavirus exposed to copper and copper alloy surfaces. Incorporation of copper alloy surfaces in conjunction with effective cleaning regimens and good clinical practice could help to control transmission of respiratory coronaviruses, including MERS and SARS.


World Health Organization.


This protocol has been designed to determine (viable) virus presence and persistence on fomites in various locations where a patient infected with COVID-19 is currently receiving care or being isolated, and to understand how this may relate to COVID-19 transmission events in these settings.

Available from:
World Health Organization.

**Surface sampling of MERS-CoV in health care settings: A practical “how to” protocol for health care and public health professionals** Geneva.; World Health Organization; 2020

The protocol provides health care and public health professionals guidance on how to investigate the role of environmental contamination during outbreaks of MERS-CoV in a health care setting where a patient infected with MERS-CoV is currently being treated. The results from such studies will be used in risk assessment and risk management of MERS-CoV hospital-acquired infections, but also for guiding the implementation and monitoring of effectiveness of infection prevention and control measures.


**Environmental contamination of the SARS-CoV-2 in healthcare premises: An urgent call for protection for healthcare workers.**

medRxiv. 2020:2020.03.11.20034546.

Importance A large number of healthcare workers (HCWs) were infected by SARS-CoV-2 during the ongoing outbreak of COVID-19 in Wuhan, China. Hospitals are significant epicenters for the human-to-human transmission of the SARS-CoV-2 for HCWs, patients, and visitors. No data has been reported on the details of hospital environmental contamination status in the epicenter of Wuhan. Objective To investigate the extent to which SARS-CoV-2 contaminates healthcare settings, including to identify function zones of the hospital with the highest contamination levels and to identify the most contaminated objects, and personal protection equipment (PPE) in Wuhan, China. Design A field investigation was conducted to collect the surface swabs in various environments in the hospital and a laboratory experiment was conducted to examine the presence of the SARS-CoV-2 RNA. Setting Six hundred twenty-six surface samples were collected within the Zhongnan Medical Center in Wuhan, China in the mist of the COVID-19 outbreak between February 7 - February 27, 2020. Participants Dacron swabs were aseptically collected from the surfaces of 13 hospital function zones, five major objects, and three major personal protection equipment (PPE). The SARS-CoV-2 RNAs were detected by reverse transcription-PCR (RT-PCR). Main Outcomes and Measures SARS-CoV-2 RNAs Results The most contaminated zones were the intensive care unit specialized for taking care of novel coronavirus pneumonia (NCP) (31.9%), Obstetric Isolation Ward specialized for pregnant women with NCP (28.1%), and Isolation Ward for NCP (19.6%). We classified the 13 zones into four contamination levels. The most contaminated objects are self-service printers (20.0%), desktop/keyboard (16.8%), and doorknob (16.0%). Both hand sanitizer dispensers (20.3%) and gloves (15.4%) were most contaminated PPE. Conclusions and Relevance Many surfaces were contaminated with SARS-CoV-2 across the hospital in various patient care areas, commonly used objects, medical equipment, and PPE. The 13 hospital function zones were classified into four contamination levels. These findings emphasize the urgent need to ensure adequate environmental cleaning, strengthen infection prevention training, and improve infection prevention precautions among HCWs during the outbreak of COVID-19.
The findings may have important implications for modifying and developing urgently needed policy to better protect healthcare workers during this ongoing pandemic of SARS-CoV-2.

**Competing Interest Statement**
The authors have declared no competing interest.

**Funding Statement**
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**Author Declarations**
All relevant ethical guidelines have been followed; any necessary IRB and/or ethics committee approvals have been obtained and details of the IRB/oversight body are included in the manuscript.

All necessary patient/participant consent has been obtained and the appropriate institutional forms have been archived.

Yes, I understand that all clinical trials and any other prospective interventional studies must be registered with an ICMJE-approved registry, such as ClinicalTrials.gov. I confirm that any such study reported in the manuscript has been registered and the trial registration ID is provided (note: if posting a prospective study registered retrospectively, please provide a statement in the trial ID field explaining why the study was not registered in advance).

Yes, I have followed all appropriate research reporting guidelines and uploaded the relevant EQUATOR Network research reporting checklist(s) and other pertinent material as supplementary files, if applicable.

Yes, the reported data are available from the corresponding authors on reasonable request. After publication of the findings, the data will be available for others upon the request. Our team will provide contact information including an email address for future communication once the data are ready to be shared with others. The detailed study plan will be needed for assessment of the reasonability to request for the data. The corresponding authors will make a decision based on the provided documents. Additional information may also be needed during the process.

https://www.medrxiv.org/content/medrxiv/early/2020/03/16/2020.03.11.20034546.full.pdf


**[Consideration and prevention for the aerosol transmission of 2019 novel coronavirus].**

*Zhonghua yan ke za zhi* Chinese journal of ophthalmology. 2020;56(0):E008.

Novel coronavirus pneumonia broke out from Wuhan, and spreading to the whole nation and world since Dec, 2019. It is now the critical stage to fight against the virus. Previous epidemiological investigations and animal experiments suggest aerosol could perform as virus transmitter. Based on the clinical observation, the possibility of aerosol transmission of 2019 novel coronavirus has aroused a lot of attention. This study focuses on the feature of aerosol transmission, and the pathogens involved in. We analyzed the possibility of aerosol transmission for the novel coronavirus. Relevant strategies to prevent novel coronavirus pneumonia are established, serving as references to the medical personnel and general public during their work or daily life. ( Chin J Ophthalmol, 2020, 56: ).


**Spatial transmission of COVID-19 via public and private transportation in China.**

*Travel medicine and infectious disease.* 2020:101626.