SCIENTIFIC STUDIES ABOUT COVID-19 AND CLEANING

In the project, PandemicClean – Safe and Effective Cleaning in Pandemic Situation, research findings will be gathered about factors affecting professional cleaning in a pandemic situation. During the three-year project at least 30 research will be documented.

This is the first research summary.

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Contents

MICROBE FINDINGS ON SURFACES, PERSISTENCE AND STABILITY ON SURFACES

Zhang, H. L. et al. 2022. SARS-CoV-2 RNA persists on surfaces following terminal disinfection of COVID-19 hospital isolation rooms.

https://www.ajicjournal.org/article/S0196-6553(22)00047-5/fulltext

Objective

- To investigate if there were SARS-CoV-2 RNA on surfaces after terminal cleaning.
- 51 patient rooms in 3 non-intensive care units were evaluated.
- 48 (94.1 %) were sampled following and 3 (5.9 %) before ultraviolet germicidal irradiation (UVGI).

Terminal cleaning

- Terminal cleaning was performed according to a checklist of surfaces.
- Virex PlusTM disposable wipes, a quaternary ammonium product, were used for all surfaces within the room with the exception of the bathroom which were cleaned with ChloroxTM sodium hypochlorite disposable wipes.
- One disposable wipe was used per surface.
- Floors were cleaned with microfiber mops and BruTabsTM, a sodium dichloro-s-triazinetrione disinfectant.
- Mops were to be used for a single patient room prior to disposal.
- Cleaning began 45 minutes or later after patient discharge to allow for settling of infectious particles.
- All rooms and bathrooms underwent ultraviolet germicidal irradiation (UVGI) after surface cleaning (Optimum-UVTM, Clorox Healthcare).
- Monitoring of cleaning effectiveness was performed by manager inspection of 30 % or more discharge rooms.
- While Adenosine triphosphate (ATP) monitoring is used in other units, visual monitoring was used primarily in COVID isolation rooms.
- There were no periods during the study where shortage or availability of cleaning supplies altered cleaning practices.

Results

- SARS-CoV-2 RNA was detected on 193 per 602 (32.1%) surfaces after terminal cleaning

- including 118 per 150 (78.7 %) floor surfaces
- 58 per 252 (23.0 %) elevated high-touch surfaces
- and 17 per 200 (8.5 %) elevated low-touch surfaces.

- Compared to COVID-19 rooms during patient occupancy

- terminally cleaned rooms had a lower prevalence of SARS-CoV-2 RNA contamination among elevated high-touch surfaces (58/252 [23.0 %] vs 272/830 [32.8 %])
- but a similar prevalence among elevated low-touch surfaces (17/200 [8.5 %] vs 77/664 [11.6 %], P = .25) and floors.

- The high prevalence of SARS-CoV-2 RNA contamination on terminally cleaned floors is of uncertain significance. Recent data suggest that hospital floors serve as an underappreciated source of pathogen dissemination via footwear, portable equipment, or contact with high-touch objects.

Tannhäuser, R. et al. 2022. Bacterial contamination of the smartphones of healthcare workers in a German tertiary-care hospital before and during the COVID-19 pandemic.

https://reader.elsevier.com/reader/sd/pii/S0196655321006696?token=46540793D5779B5E190FFBE68451A637C1AA3B763B8B0DFEA0AD10525F67E74CB353D8719F9925D0AD5EA944652FA8A2&originRegion=eu-west-1&originCreation=20220407152331

Objective

- To investigate bacterial colonization on smartphones (SPs) owned by healthcare workers (HCWs) before (2012) and during the pandemic (2021).
- Only the screens were investigated, not the back side of phones.

Methods

- Devices underwent sampling under real-life conditions, without prior manipulation.
- Isolates were identified by MALDI-TOF mass spectrometry and underwent microbiological susceptibility testing.

Results

- On 293 of 295 SP screens (99.3 %) bacterial contamination was present.
- The most common bacteria found was coagulase-negative staphylococci (CNS = bacteria that commonly live on a person's skin)
    - in 2012, 80 of 99 SPs (80.8 %), and
    - in 2021, 147 of 196 SPs (75 %)
- The second largest group was spore forming aerobic bacteria
    - in 2012 (37 of 99, 37.4 %)
    - in 2021 (130 of 196, 66.3 %)
- Polymicrobial contamination was detected
    - in 2012 on 54 of 99 SPs (54.5 %), and
    - in 2021 on 155 of 196 SPs (79.1 %)
- Almost all bacteria detected can cause infections in critically ill patients, especially those with immunosuppression.
- Methicillin-resistant S. aureus (MRSA) was not detected in 2012, but on 3 SPs (1.5 %) in 2021. Also, a higher rate of enterococci was detected on SPs in 2021 (35 out of 196, 17.8 %) compared to 2012 (3 out of 99, 3.3 %).
- Cleaning the smartphone
    - in 2012 at least daily 23.2 %, when obviously contaminated 68.7 %, no cleaning 8.1 %.
    - in 2021 at least daily 45.9 %, when obviously contaminated 50,5 %, no cleaning 3.6 %.

Mody, L. et al. 2021. Environmental contamination with SARS-CoV-2 in nursing homes.

https://agsjournals.onlinelibrary.wiley.com/doi/10.1111/jgs.17531

Objective

- To investigate frequency and persistence of SARS-CoV-2 on surfaces.

Methods

- Samples (2087 swabs) were taken (with 241 visits)
    - from rooms of 104 Covid-19 patients (total, 1896 samples): bed controls, call button, bedside tabletop, TV remote, privacy curtain, windowsill, toilet seat, doorknob, and air vent (if within reach)
    - from nearby common areas (191 samples): sitting area tabletop, sitting area chair or arm rest, dining room tabletop, nurses' station tabletop, nurses' station computer keyboard, and elevator buttons.
- For all flat surfaces, an area of approximately 5 x 20 cm was swabbed. For smaller objects, the entire surface was swabbed.
- 3-month study period.

Results
- SARS-CoV-2 positivity was 28.4 % (538/1896 swabs) on patient room surfaces and 3.7 % (7/191 swabs) on common area surfaces.
- Nearly 90 % (93/104) of patients had SARS-CoV-2 contamination in their room at least once
- TV remotes were most likely to be contaminated, with 68.1 % and the contamination was most persistent, often detected on both enrollment and during follow-up (34 %; 16/47).
- Patients with greater independence are more likely than fully dependent patients to contaminate their immediate environment.

Abney, S.E. et al. 2021. Toilet hygiene—review and research needs.

https://sfamjournals.onlinelibrary.wiley.com/doi/full/10.1111/jam.15121

Research results
- The build-up of biofilm within a toilet bowl/urinal including sink can result in the persistence of pathogens and odours.
- During flushing, pathogens can be ejected from the toilet bowl/urinal/sink and be transmitted by inhalation and contaminated fomites.
- Use of automatic toilet bowl cleaners can reduce the number of microorganisms ejected during a flush.
- Salmonella bacteria can colonize the underside of the rim of toilets and persist up to 50 days.
- Pathogenic enteric bacteria appear in greater numbers in the biofilm found in toilets than in the water.

- Source tracking of bacteria in homes has demonstrated that during cleaning enteric bacteria are transferred from the toilet to the bathroom sinks and that these same bacteria colonize cleaning tools used in the restroom.
- Quantitative microbial risk assessment has shown that significant risks exist from both aerosols and fomites in restrooms.
- Cleaning with soaps and detergents without the use of disinfectants in public restrooms may spread bacteria and viruses throughout the restroom.
- The toilet bowl could potentially contain up to 10^{14} virus particles.

Aerosols produced by flush toilets
- Significant aerosolization can occur resulting in potential transmission of pathogens by inhalation and via fomite contamination (Sars-CoV-2 also).
- Large droplets settle out within a few minutes, smaller may persist and continued to settle out on surfaces for 90 min.
- Residual levels of microorganisms may remain in the bowl after the initial flush, resulting in aerosolization of bacteria after repeated flushes.
- In a seeded toilet experiment, Salmonella could be isolated from the air, the toilet seat and lid following flushing of the toilet. In bowl water Salmonella was found for 5 days and was isolated from the biofilm below the water line in the bowl for up to 50 days.

Surface fomite contamination
- *P. aeruginosa* and *E. coli* as well as other Enterobacteria has frequently been found on sites such as the toilet seat and handle in addition to the toilet bowl.
- Viruses can maybe persist on biofilms for long periods of time.
- Several studies have reported the contamination of hospital patient toilets shared by patients. In South Africa found that 53–63 % of the restroom surfaces were contaminated with SARS-CoV-2. Highest amounts on the toilet seat and the cistern flush handle.
- SARS-CoV-2 virus has been recovered from toilet seat, bathroom door handle and sinks in bathrooms housing patients with SARS-CoV-2 infections.

Impact of cleaning on spread of enteric pathogens in restrooms
- A research made in US households showed that in seven of the eight homes with identified faecal coliforms, identical strains were isolated from either the toilet itself (toilet bowl, toilet seat bottom, flush handle) or the cleaning tool and at least two other surfaces (up to eight

surfaces) in the bathroom (e.g., sink bowl, sink drain, sink countertop, sink faucet handle, shower/bath drain, shower/bath surface, floor 12 inches in front of the toilet).

Risk assessment of infections from restroom use

According to estimated Quantitative microbial risk assessment (QMRA) the risk of infection from SARS-CoV-2 from touching various surfaces in public restrooms

- The greatest risk of infection (4.3×10^{-2} to 6.0×10^{-4}) is when a person uses the toilet once in a day increasing to 1.0×10^{-1} to 1.4×10^{-3} if they used the toilet three times in a day.
- Risks of infection for a one-time exposure are considered significant if less than 1×10^{-6}.

Conclusions

- Use of disinfectants is critical to preventing movement of enteric microorganisms throughout the restroom.
- Colonization of biofilms and hard to clean area (the rim under the toilet) by pathogenic enteric bacteria such as Salmonella appear to be a problem.

Ding, Z. et al. 2020. Toilets dominate environmental detection of severe acute respiratory syndrome coronavirus 2 in a hospital.

https://www.sciencedirect.com/science/article/pii/S0048969720352396

Methods

107 surface samples were taken

- 37 from toilets
- 34 from other surfaces in isolation rooms, and
- 36 from other surfaces outside the isolation rooms in the hospital.

Results

4 of these samples were positive

- 2 ward door handles,
- 1 bathroom toilet seat cover, and
- 1 bathroom door handle

Three were weakly positive

- 1 bathroom toilet seat
- 1 bathroom washbasin tap lever, and
- 1 bathroom ceiling exhaust louver.

Vasickova, P. et al. 2010. Issues Concerning Survival of Viruses on Surfaces.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7091010/

According to the article, the survival of the virus on surfaces is affected by a combination of biological, physical, and chemical factors.
- Anyhow, complete information regarding the influence of the environment on all viruses and their stability in external conditions does not exist.
- Persistence of a virus in the environment is primarily affected by the presence of a viral envelope.

The article also states some data of viruses' ability to spread infections.
- A critical factor of viral transmission is its ability to survive in the environment.
- Even if some viruses survive relatively poorly in the environment, the low infective dose suggests that these viruses are able to persist in sufficient numbers to act as a source of infection for several days, week or in some cases months.
- Rapid spread of viral infections through contaminated surfaces is common particularly in crowded indoor establishments such as schools, day-care facilities, nursing homes, business offices, hospitals, or transport systems.

- Nearly one thousand different types of viruses are known to infect humans, whilst the most common viral illnesses are produced by enteric and respiratory viruses.
- It has been demonstrated that infective viral particles can survive on human hands and be transferred to animate and non-porous surfaces.
- E.g., once the surface is contaminated, at least 14 persons could be contaminated or infected by touching a polluted door handle.
- Successive transmission of virus from one person to another could be followed up to the sixth contact person.
- Contaminated fingers could subsequently transfer a virus from up to seven clean surfaces.
- Persistence of a virus in the environment is primarily affected by the presence of a viral envelope
    - Non-enveloped viruses (e.g., rotavirus, norovirus) have higher resistance to drying or desiccation methods and therefore are spread more easily than enveloped viruses (e.g., SARS-, influenza virus)
    - e.g., rotavirus can be infective on surfaces for at least 2 months
    - but respiratory viruses usually remain infectious for several hours to several days.
- Variation in virus survival occurs within a viral family or even genus.
- Effect of relative humidity (RH) and temperature varies within virus type.
- Ultraviolet radiation is the crucial virucidal agent.
- The majority of viruses remain viable for a longer period of time on non-porous materials, although there are exceptions.
- The extent and state of virus adsorption on surfaces has an important influence on virus survival.
- Data about the influence of other microorganisms on virus survival are contradictory.
    - Virus survival may increase or decrease with the number of microbes present on the surface.
    - Environmental isolates of bacteria with antiviral ability have been found.
    - Viruses can penetrate to biofilms and benefit from them.

Singh, D. et al. 2021. Viral load could be an important determinant for fomites-based transmission of viral infections.

https://pubmed.ncbi.nlm.nih.gov/34041100/#affiliation-1

Objective

- To investigate viral pathogens on surfaces.

Method

- Viral samples were categorized using the cycle threshold (Ct) values
    - high (17 to < 24), moderate (24 to < 31), or mild (31 to < 38) viral load.
- Samples were smeared on commonly used cardboard surface (absorbent surface) and stainless steel (non-absorbent surface).
- After 90 min the samples were analysed.

Results

- Viral load/titter positively correlated with the viral material on surfaces.
- Higher viral load (low Ct) samples exhibited higher probability of being detected on the surfaces than those samples with lower/moderate (high Ct) viral load.

Conclusion

- Common inanimate surfaces are potential source of the viral transmission.
- However, the viral load on these surfaces is key determinant of such transmission.

SPREAD OF MICROBES

Sifuentes, L.Y. et al. 2016. Use of ATP Readings to Predict a Successful Hygiene Intervention in the Workplace to Reduce the Spread of Viruses on Fomites.

https://www.researchgate.net/publication/306308747_Use_of_ATP_Readings_to_Predict_a_Successful_Hygiene_Intervention_in_the_Workplace_to_Reduce_the_Spread_of_Viruses_on_Fomites

Objective

Research how viruses spread in an office environment (80 full-time employees)
- from hand to surface
- from one surface to another, and
- whether ATP measurement results and virus levels measured from surfaces correlate.

Test were made before and after instructing staff in hygiene practices.

- As a hygiene practice: handcuffs, face wipes and surface disinfectant wipes were provided, and their correct use and use were instructed.

Methods

- MS-2 bacteriophage used, 6×10^9 / cm^2
- It was placed to a handle after the lift lobby (50 cm^2) before staff arrive and to one volunteer's hand.
- Surfaces (54 different surfaces) and hands of other subjects (42 persons) were tested after 4 and 7 hours of soiling.
- The surfaces were table and countertops, the handles of the refrigerator, the microwave oven and the coffee pot, the buttons of the vending machine.

Results and conclusions

Inoculation of one employee’s hand:

- Without hygiene instruction:
  - After 4 hours, bacteriophage was found in 56 % of the surfaces examined, after 7 hours in 63 %.
- After hygiene instruction
  - Amounts: after 4 hours 9 %, after 7 hours 30 %

Inoculation of door handle:

- After hygiene instruction, there was 70 % fewer fomites contaminated after 4 h.
- There was no direct correlation between the results of ATP measurements and the results of surface virus measurements, but both measurement methods showed lower readings after guidance on hygiene practices.

- Conclusion: Although ATP measurement does not measure the number of viruses, the method is suitable for situations where the effect of different procedures, such as changes in hygiene practices, is tested.

CLEANING DETERGENTS AND DISINFECTANTS

Tuladhar, E: et al. 2012. Residual Viral and Bacterial Contamination of Surfaces after Cleaning and Disinfection.

https://journals.asm.org/doi/full/10.1128/AEM.02144-12

Objective

- To investigate the efficacy of cleaning and disinfection procedures for reducing contamination

- by noroviruses, rotavirus, poliovirus, parechovirus, adenovirus, influenza virus, *Staphylococcus aureus*, and *Salmonella enterica*
- from artificially contaminated stainless-steel surfaces.

Results

- After a single wipe with water, liquid soap, or 250-ppm free chlorine solution,

- the numbers of infective viruses and bacteria were reduced by 1 log10 for poliovirus and close to 4 log10 for influenza virus.
- There was no significant difference in residual contamination levels after wiping with water, liquid soap, or 250-ppm chlorine solution.
- When a single wipe with liquid soap was followed by a second wipe using 250- or 1,000-ppm chlorine, an extra 1- to 3-log10 reduction was achieved, and
- except for rotavirus and norovirus genogroup I (extra reduction 1-3 log10), no significant additional effect of 1,000 ppm compared to 250 ppm was found.
- A reduced correlation between reduction in PCR units (PCRU) and reduction in infectious particles suggests that at least part of the reduction achieved in the second step is due to inactivation instead of removal alone.

- They used data on infectious doses and transfer efficiencies to estimate a target level to which the residual contamination should be reduced and found that
    - a single wipe with liquid soap followed by a wipe with 250 ppm free chlorine solution was sufficient to reduce the residual contamination to below the target level for most of the pathogens tested.

Cleaning methods
- wet wiping (surface was dried in 3 minutes)
- only cleaning
- cleaning + disinfection.

Conclusions
- The enveloped respiratory influenza A virus has higher sensitivity to disinfection than the nonenveloped enteric viruses.
- The two-step procedure consisting of a single wipe with liquid soap followed by a disinfection step using 250-ppm chlorine solution is likely to be a good intervention strategy in cases of viral respiratory disease outbreaks.

El-Azizi, M. et al. 2016. Efficacy of selected biocides in the decontamination of common nosocomial bacterial pathogens in biofilm and planktonic forms.

https://pubmed.ncbi.nlm.nih.gov/27477508/

Objective
- Tested how efficiently
    - glutaraldehyde (GLA)
    - hydrogen peroxide (HPO)
    - peracetic acid (PAA)
    - sodium hypochlorite (SHC)

remove bacteria in planktonic and biofilm forms.
- Bacteria in the study: *Acinetobacter baumannii, Burkholderia cepacia, Enterococcus faecalis, Enterococcus faecium, methicillin resistant Staphylococcus aureus (MRSA), Staphylococcus epidermidis, Pseudomonas aeruginosa, Stenotrophomonas maltophilia*, and one reference strain of *Escherichia coli.*

Evaluation of the killing activity of the biocides

- Against the planktonic phase of bacteria, the minimum bactericidal concentrations of the biocides required to kill all bacteria (MBC_{100}) were determined
- Against the biofilms of bacteria using an in vitro biofilm device the minimum concentrations of biocide required to kill 85% of bacteria in the biofilms (MBC_{85}) were determined
- Scanning electron microscopy (SEM) was used to visualize the effect of *S. epidermidis* pre-exposure to sublethal concentrations of PAA on biofilm formation.

Results
- All biocides completely killed all nine types of bacteria in the planktonic phases at all concentrations and at all exposure times, but there was a big variation of the biocide concentration needed.
- The biofilms were significantly less susceptible to the biocides than were planktonic cells of the same microorganism.
- Note: No products, according to the guideline, are CDC-recommended, EPA-registered, or FDA-cleared for the eradication of microorganisms from biofilms. This means that all listed chemicals are only recommended for combating micro-organisms in the planktonic form.

Russel, A. D. 2003. Similarities and differences in the responses of microorganisms to biocides. (Article)

https://academic.oup.com/jac/article/52/5/750/760065

From the article
- Unlike antibiotics, biocides are multi-targeted antimicrobial agents.

- There is considerable variation in the response of different microorganisms to biocides.
- Reasons for these varied responses are poorly understood at present.
- Few biocides are bactericidal (including mycobactericidal), sporicidal, virucidal and fungicidal.
- Most are bactericidal (with or without being mycobactericidal), virucidal and fungicidal but do not inactivate spores.
- Some biocides show activity against protozoa and algae.
- Factors that affect antimicrobial activity are well documented
  - period of contact
  - concentration
  - temperature
  - pH
  - presence of organic soiling matter, and
  - type of organism.
- Article presents the mechanisms how different disinfectant agents kill microbes
  - aldehydes, cationic biocides, alcohols, chlorine compounds, iodine and iodophors, peroxygens, phenols, phenylether (triclosan), organic acids and esters, metal ions, alkylating agents.

Kampf, G. et al. 2020. Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents.

https://www.journalofhospitalinfection.com/action/showPdf?pii=S0195-6701%2820%2930046-3

Review article, collecting data of HCoV, MERS-CoV, SARS-CoV, MVH, TGEV

Persistence of coronavirus on inanimate surfaces

- Most data were described with the endemic human coronavirus strain (HCoV-) 229E.
  - On different types of materials, it can remain infectious for from 2 hours up to 9 days.
- A higher temperature such as 30°C or 40°C reduced the duration of persistence of highly pathogenic MERS-CoV, TGEV and MHV.

- However, at 4°C persistence of TGEV and MHV can be increased to 28 days.

Inactivation of coronaviruses by biocidal agents in suspension tests
- Few comparative data obtained with SARS-CoV indicate that persistence was longer with higher inocula.
- In addition, it was shown at room temperature that HCoV-229E persists better at 50 % compared to 30 % relative humidity.

Inactivation of coronaviruses by biocidal agents in carrier tests
- Ethanol at concentrations between 62 % and 71 % reduced coronavirus infectivity within 1 min exposure time by 2.0-4.0 log10.
- Concentrations of 0.1-0.5 % sodium hypochlorite and 2 % glutardialdehyde were also quite effective with > 3.0 log10 reduction in viral titre.

MICROBE RESISTANCE TO DISINFECTANTS

Stone, W. et al. 2020. Disinfectant, Soap or Probiotic Cleaning? Surface Microbiome Diversity and Biofilm Competitive Exclusion.

https://www.researchgate.net/publication/346687405_Disinfectant_Soap_or_Probiotic_Cleaning_Surface_Microbiome_Diversity_and_Biofilm_Competitive_Exclusion

Method
- The type and amount of the microbiome of hospital surfaces were studied when cleaning the surfaces for 8 months with different cleaning programs
- soap-based cleaner
- probiotic cleaner (only bacterial spores of the genus Bacillus) and
- disinfectant (chlorine)
- tap water as control

- on stainless steel, ceramic tile, and linoleum surfaces
- *Staphylococcus* aureus and *E.coli* were placed to the surfaces.

- Wet wiping methods except for the probiotic, which was a ready-to-use solution: it was sprayed on the surface, after which the surface was wiped.
- Cleaning twice a week
- Test tiles were stored indoors and outdoors (on the roof of the building)
- The microbial diversity and number of test surfaces were examined after 8 months, the cleaning wipes used were also examined
- Pathogens *(P. aerugonosa*) were then added to the surfaces and microbial changes were examined.

Results

- The disinfectant reduced the amount of microbiota on the surfaces, which allowed room for the growth of pathogenic bacteria.
- Soap did not reduce the number of microbes as much as the disinfectant.
- When cleaned with soap, the microbiome was more diverse than when cleaned with a probiotic (perhaps because there is only one bacterial spore in the probiotic).
- When the probiotic was cleaned, the amount of microbiome was significantly higher than when other substances were used, which prevented the growth of pathogens on the surfaces, but when biofilm on the surface, the probiotic-induced microbiome was not as effective as soap-induced microbiome.
- 1-5 times more microbiomes on surfaces cleaned with probiotics than on other surfaces (order: disinfectant, soap, water, probiotic).
- Microbial levels of cleaning wipes were higher than on surfaces.

Conclusions

- The results support the notion that the surface microbiome can defeat pathogens.
- Both the number and the diversity of the microbiome matter.
- The use of soap and probiotics is possible in certain hospital settings.
- Probiotics should potentially contain more than one species of bacteria.
- No probiotics are needed at home.

Global AMR Insights Ambassador Network. 2021. The potential impact of the COVID-19 pandemic on global antimicrobial and biocide resistance: an AMR Insights global perspective.
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8083476/

An article of pandemic's effect on global antimicrobial resistance (AMR)
- Global infections due to antimicrobial resistant pathogens result in approximately 700 000 deaths annually, which has been estimated to increase to 10 million deaths by the year 2050. In 2019, ECDC reported the deaths of 25 000 patients in high-income countries of Europe.
- While the emergence of AMR continues to increase, there has been a decline in the availability of newly developed antimicrobial agents. If this continues, most of the currently prescribed antibiotics applied for human and animal infections will be ineffective within a decade, leading to conditions similar to that of the pre-antibiotic era.

Increased use of biocides
- Biocides = compounds with antiseptic, disinfectant or preservative activity.
- Less is known about the mechanisms and extent of microbial resistance to biocides than is known about microbial resistance to antibiotics.
- Improved hygiene practices involving biocides may actually reduce the transmission of antimicrobial-resistant pathogens that are found on our hands, but paradoxically may at the same time select for antimicrobial-resistant pathogens, thereby having an unknown impact on global AMR.
- Surface disinfectants and household cleaners contribute to an increased concentration of these substances in wastewater treatment plants and receiving waters, altering the normal ecosystem, and potentially favouring the emergence of AMR due to biocide-related selection pressure.
- The increased use of disinfectants may induce organisms to a viable but non-cultivable state, becoming undetectable using standard culture-based detection methods.

HEALTH AND SAFETY ASPECTS OF DETERGENTS AND DISINFECTANTS

Chen, Z. et al. 2021. High concentration and high dose of disinfectants and antibiotics used during the COVID-19 pandemic threaten human health.

https://enveurope.springeropen.com/articles/10.1186/s12302-021-00456-4

Article about the promoting effects of disinfectants and antibiotics on antibiotic resistance genes (ARGs) and even antibiotic resistant bacteria (ARB)

Quotes from the article:
The scientific evidence indicate that the high concentration and high dose of disinfectants and antibiotics promote the evolution toward antimicrobial resistance through horizontal gene transformation and vertical gene transformation, which threaten human health.
- Many environmental studies focus on the occurrence of disinfectants by-products (DBPs) and antibiotics residuals in diverse environments and their toxic effects on various organisms.
- Most of the emerging DBPs were found to induce oxidative stress, DNA damage, and activate DNA repair system at environmental concentrations.
- Chronic toxicological studies pointed that exposure to DBPs may induce genotoxicity, cytotoxicity, asthma, skin rashes, bladder, and colon cancer in humans.
- Disinfectant by-products and antibiotic residues permanently existed in diverse environments, which can persistently promote bacterial evolution toward antimicrobial resistance (AMR).
- Bacteria, only carrying antibiotic resistance genes (ARGs), can survive and persist in these contaminated environments.
- Expansions in the diversity and abundance of ARGs were hence presented in water, soil and air, which may disturb the normal microflora.
- Emergence of resistance amongst bacteria in the normal flora and distribution of resistant genes can contribute to an increased load of resistant, potentially pathogenic microorganisms and reduce the colonization resistance leading to overgrowth of exogenic pathogens.
- New ARB, such as the COVID-19, could be a result of ARGs enrichment and microflora disturbance, and it hence increased and spread rapidly all over the world in recent years.

- Human health studies reported that the ARGs and ARB were frequently detected in animal and human gut.
- High concentration and high dose of disinfectants and antibiotics used during the COVID-19 pandemic, which entered into environments, are definitely accelerating the target selection of AMR in environments.
- Further research have to pay more attention on the enrichment, bioaccumulation and biomagnification of disinfectants, antibiotics, ARGs and even ARB in human bodies.

CLEANING EQUIPMENT

Robertson, A. et al. 2019. Combining detergent/disinfectant with microfibre material provides a better control of microbial contaminants on surfaces than the use of water alone.

https://orca.cardiff.ac.uk/123553/3/Combining%2Bdetergent_disinfectant%2Bwith%2Bmicrofibre%2Bmaterial%2Bprovides%2Ba%2Bbetter%2Bcontrol%2Bof%2Bmicrobial%2Bcontaminants%2Bon%2Bsurfaces%2Bthan%2Bthe%2Buse%2Bof%2Bwater%2Balone.pdf

Objective
- To investigate the impact of using
  - water vs quaternary ammonium compounds (QAC)-based detergent/disinfectant
  - or water vs sporicidal products
  - in combination with a microfibre material.
- Measurements made without and with organic load
- The ASTM2967-15 standard test method was used to measure wipe products' efficacy: bacteria/spores removal from, and transfer between surfaces.

Methods
- *Staphylococcus aureus* and *Acinetobacter baumannii* and spores of *Clostridium difficile* were used

- Materials: stainless steel and PVC with PUR-coating
- A 10-s wiping time with 300 g weight was used with the detergent/disinfectant and sporicidal products as it reflects the conditions of use in practice.
- For the transfer experiment, the used wipe was used to wipe a clean surface (10 s, 300 g) immediately after the initial wiping.

Results

- There was a significant difference in the number of bacteria removed from surfaces following wiping between the use of water alone and the detergent/disinfectant product, regardless of the type of surface.
- Wiping with water
    - Reduced bacterial counts mostly by 1-2 log10, but
    - bacterial transfer from the microfibre to a different surface following wiping was significant (3-4 log10 bacterial transfer).
- Wiping with detergent/disinfectant
    - Reduced bacterial counts by 3-5 log10.
    - Significantly prevented the transfer of bacteria to clean surface.
- Wiping with sporicidal product
    - Significantly reduced the concentration of *C. difficile* spores comparing to the use of water regardless of the type of surfaces and organic load.
    - Prevented the transfer of *C. difficile* spores between surfaces, regardless of the type of surfaces or level of organic load.
    - The use of water was associated with significant spore transfer 15 min post-wiping or 24 h after wiping.
- The level of organic load did not affect the efficacy of the test product and material performance.

Conclusions

- The use of water alone with a microfibre cloth is less effective and should not replace the use of biocidal products.

Smith, D.L. et al. 2011. Assessing the efficacy of different microfibre cloths at removing surface micro-organisms associated with healthcare-associated infection.

https://pubmed.ncbi.nlm.nih.gov/21501897/

Objectives

- To investigate the ability of 10 different microfibre cloths (one disposable, 9 re-usable)
    - to remove microbial contamination (methicillin resistant *Staphylococcus aureus* (MRSA), *Clostridium difficile* (in spore form) and *Escherichia coli*
    - from three surfaces commonly found in hospital settings (stainless steel, furniture laminate and ceramic tile),
    - under controlled laboratory conditions.
- To study the effect of laundry to cloths.
- To study the effect of repeat cloth use.

Methods

- One hour prior to testing, cloths were placed in separate plastic bags and dampened with volumes (as per manufacturer's instructions) of sterile distilled water.
- Surface cleaning trials were conducted using a custom-made automated cleaning rig.

Results

- The mean reduction of micro-organisms was 2.21 log10.
- No significant differences between microfibre cloths /except disposable cloth, was the worst).
- The performance of all cloths decreased with repeated use on a succession of contaminated surfaces.
- After repeated washing, re-usable cloth performance improved at 75 washes, and reduced after 150 washes, although, in most instances, performance after 150 washes was better than at first wash.

Terpstra, P. M. J. et al. 2015. Efficiency of multi-use micro fibre flat mops versus disposable micro fibre flat mops.

https://www.vsr-schoonmaak.nl/cms/files/2018-09/1537955848_publicatie-efficiency-of-multi-use-micro-fibre-flat-mops-versus-disposable-micro-fibre-flat-mops.pdf

Objectives

- To test and compare the effectiveness aspects of disposable micro fibre flat mops to multi-use micro fibre flat mops in a controlled laboratory research study, using practical simulation.
- The effectiveness aspects compared: the cleaning action, cleaning exertion, dirt-binding capacity and hygienic effectiveness.

Materials

- 4 multi-use and 4 disposable flat mops dampened with a detergent solution.
- Floor materials: linoleum, vinyl and stone tiles.
- A cleaning robot was used, so that the cleaning pressure, the length of the wiping movement and the wiping speed could be adjusted.
- Three types of test dirt: chocolate milk, sebaceous matter and street sweepings, and for hygiene tests a culture that contained a mixture of micro-organisms.
- The cleaning pressure value was determined for normal/light cleaning, normal/intensive cleaning and thorough/localised cleaning.
- The number of wiping movements required to remove a stain was recorded as a measure of cleaning speed.
- The result of a visual assessment of the dry, cleaned surface was a measure for cleanliness.

Results

- On average multi-use micro fibre mop was better to remove all the test dirt.
- There were, however, differences within mops.
- The frictional resistance of both the multi-use and the disposable flat mops differed significantly within their respective groups. The highest cleaning resistances were measured with the disposable flat mops and the lowest with the multi-use.

- With one exception, all in all the flat mops removed a stain with a substantial amount of the germs present within it. The log reduction was from 2.0 to 2.7 (99.0 to 99.8 % of the present germs).

Terpstra, P. M. J. 2021. Scrubber drier hygiene.

https://www.vsr-schoonmaak.nl/cms/files/2021-04/1618991742_brochure-vsr-hygi-ne-schrobzuigmachine-web-eng.pdf

Objective

- During the use, can scrubber driers spread through the air microorganisms that have been removed from the floor together with dirt.

Methods and results

Two series of experiments

- Was the liquid in the wastewater tank contaminated with microorganisms after use in a practical situation.
    - Substantial numbers of microorganisms were found in all wastewater tanks of the scrubbing machines that were investigated. The average germ count measured per hospital varies from 4.4 to 7.1 log TPC/ml.
- Were the microorganisms in the vacuumed cleaning fluid spread into the ambient air during scrubbing.
    - The result of the study implies that there is no indication that scrubbing and drying with a medium-sized conventional single-disc scrubber drier
        1) spreads microorganisms removed from the floor into the ambient air, and
        2) that users/residents of an area in which scrubbing takes place and/or the person operating the scrubber drier are exposed to a hygiene risk as a result.

Terpstra, P. M. J. & van Kessel, I. 2018. Hygiene of Refillable Spray Bottles.

and

Terpstra, P. M. J. et al. Hygiene of refillable spray bottles II.

https://www.vsr-schoonmaak.nl/cms/files/2021-06/brochure-vsr-rapport-sproeiflacons-engels-web.pdf

Objectives, study I

- To explore if spray bottles in the institutional cleaning sector are microbially contaminated, and if so, pose a hygiene risk.
- If a microbial contamination does exist, to determine whether the organisms are freely found in the residual liquid in the spray bottles (free germs) or also in any biofilm (bound germs).
- To determine whether an existing contamination can be eliminated with a single hygienic treatment using a disinfectant (active chlorine).

Results, study 1

- The liquid in refillable spray bottles used in institutional practice may be microbially contaminated.
- Germs were found in 33 of the 55 spray bottles examined.
- The degree of contamination ranged from 3.0 log CFU up to 9.0 log CFU per spray bottle.
- The spray bottles contained both free germs and bound germs.
- The numbers of bound germs were in the same order of magnitude as the numbers of free (unbound) germs.
- A single hygienic treatment of contaminated spray bottles does not result in uncontaminated spray bottles.

Objectives, study II

- To investigate to what extent the hygiene of spray bottles in institutional cleaning practice improves with the application of a daily hygienic treatment in compliance with the guidelines of the Dutch Working Party on Infection Prevention (WIP) and the Dutch National Institute for Public Health and the Environment (RIVM).

Methods and results

Laboratory study

- Spray bottles were exposed to an infected cleaning agent for 6 hours every day for a period of 14 and 28 days.

- Half of the spray bottles in the study were treated hygienically (daily) after exposure in accordance with the WIP/RIVM guidelines; the other half received no hygienic treatment (only emptying).
- A neutral daily cleaner, a neutral interior cleaner and an alkaline sanitary cleaner were used as cleaning agents.

- The spray bottles that were exposed to contaminated sanitary cleaner and treated hygienically remained uncontaminated.
- In all other spray bottles, contamination was found after 14 and 28 days.

Field study

- Unused new spray bottles were issued at 7 Dutch healthcare institutions.
- The cleaning staff were requested to use the spray bottles in their normal daily routine.
- The spray bottles had to be treated hygienically at the end of every working day in compliance with the hygiene guidelines of the WIP/RIVM.
- After a period varying from 11 to 52 days, the spray bottles were collected for hygienic examination.

- In 3 of the 7 institutions, no contamination was found in any of the spray bottles used.
- In 4 institutions contamination to a greater or lesser degree was found.
- The infection rate for the contaminated bottles ranged from 3.2 to 7.0 log CFU.
- Comparison of this result with previous research provides indications that the average and maximum degree of contamination is reduced by a hygienic treatment in compliance with the WIP and RIVM.

CLEANING METHODS

Edwards, N. W. M. et al. 2020. Recontamination of Healthcare Surfaces by Repeated Wiping with Biocide-Loaded Wipes: “OneWipe, One Surface, One Direction, Dispose” as Best Practice in the Clinical Environment.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7766459/

Objectives

- To study how the surface to be wiped, the type of fibre in the wipe and how the presence of liquid biocide affects the degree of recontamination.
  - metal, ceramic, and plastic healthcare surfaces
  - 2 different wipe compositions (hygroscopic and hydrophilic)
  - with and without liquid biocide.

Results

- Despite initially high removal efficiency of >70 % during initial wiping, all healthcare surfaces were recontaminated with *E. coli, S. aureus and E. faecalis* when wiped more than once using the same wipe.
- Recontamination occurred regardless of the fibre composition of the wipe or the presence of a liquid biocide.
- The extent of recontamination by *E. coli, S. aureus and E. faecalis* bacteria also increased when metal healthcare surfaces possessed a higher microscale roughness (<1 µm).

Conclusions

"One wipe, One surface, One direction, Dispose" policy should be implemented and rigorously enforced.

Berendt, A.E. et al. 2011. Three swipes and you're out: How many swipes are needed to decontaminate plastic with disposable wipes?

https://pubmed.ncbi.nlm.nih.gov/21306797/

Objective

- To measure the ability of various wipes to reduce bacterial counts when swiped across plastic 1, 3, or 5 times.

Methods

- Dilutions of 0.5 McFarland (1.5 3 108 colony-forming units/ml) suspensions of methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant.
- *Enterococcus faecalis* (VRE), and *Pseudomonas aeruginosa*, as well as a 2.0 McFarland suspension of *Candida albicans*, were prepared in sterile saline.
- To mimic contaminate surfaces, 100 ml of each suspension were streaked evenly onto sterile plastic Petri dishes and allowed to dry.
- Each dish was then rubbed 1, 3, or 5 times with
  - a saline-moistened tissue (saline= water and salt, sodium chloride, NaCl), wet wiping
  - a 5% ethanol wipe
  - a quaternary ammonium wipe with 14.30 % isopropanol and 0.23 % di-isobutylphenoxyethyl dimethyl benzyl ammonium chloride
  - a 0.5 % hydrogen peroxide wipe
  - a 0.5 % chlorhexidine-70 % isopropyl alcohol wipe.
- Contact time 1 second per swipe (after allowed to dry 10 min).
- The plate surfaces were then flooded with 1 ml of trypticase soy broth, to resuspend any remaining bacteria.
- 100 µl of the suspension was cultivated on blood agar plates for 24 hours and colonies calculated after that.

Results
- For all 5 wipe types, swiping the surface 3 or 5 times eliminated more bacteria than only one swipe.
- According to authors, “dramatic decreases” in bacterial counts with an increasing number of swipes, regardless of the type of wipe used (including saline-moistened tissues)
- Swiping 3 times decreased the bacterial load by 88% (on average) relative to swiping just once.
- When the surface was swiped 3 or more times, the saline wipe appeared to be equally effective as disinfectant wipes.

Conclusions
- When surfaces are swiped 3 or more times, a saline-moistened wipe appears to be just as effective as disinfectant wipes.
- When swiped only once, then a disinfectant wipe should be used.

Edwards, N. W. M. et al. 2018. Factors affecting removal of bacterial pathogens from healthcare surfaces during dynamic wiping.
https://journals.sagepub.com/doi/10.1177/0040517517753632

Objectives

- To determine the intrinsic (e.g., wipe surface density, lotion addition to wipe) and extrinsic (e.g., wiping pressure) factors leading to the greatest bacterial removal efficiencies.

Methods

- Test microbes: *E. coli, S. aureus*, and *E. faecalis*
- Wipes were manufactured for the research in laboratory
  - an inherently hydrophilic regenerated cellulose fiber (lyocell) and
  - an inherently hydrophobic fiber (polypropylene – PP) were selected as raw materials for wipe fabric manufacture
  - with different properties.
- Wiping pressures were selected based on those produced by an average sized human hand and the median value reported in the literature.
  - “Low” wiping pressure of 0.69 $kN.m^{-2}$ is the equivalent of 1 kg of exerted force from an average sized human hand (‘‘hand-weight’’).
  - “Medium” wiping pressure of 4.68 $kN.m^{-2}$ is equivalent to 6.79 kg ‘‘handweight’’. This was selected by extrapolating the 150 g ‘‘exerted weight’’ used by Ramm et al. in their wiping experiments.
  - “High” 13.80 $kN.m^{-2}$ wiping pressure is the equivalent of 20 kg ‘‘hand-weight’’.
- The influence of a biocidal liquid was compared with distilled water and dry controls
  - Biocide was a blend of a non-ionic surfactant (C9–C11 ethoxylated alcohol pareth-5), a cationic surfactant (benzalkonium chloride) and various buffering agents and sequestrants.
- Wiping done with a certain rotation device 60 r min^{-1} for 10 s at either 0.68, 4.69 or 13.80 $kN.m^{-2}$.

Results

- The addition of a biocide to a wipe has the greatest effect on bacterial removal %.

- The improvement in wiping efficiency due to the addition of the biocidal liquid might also be partly due to the presence of a liquid phase, and not just the fact that it is a biocidal liquid.
- The addition of water alone can substantially increase bacteria removal from the surface by providing a transport medium in which bacteria can be suspended and transported by the interstitial pore spaces within the wipe fabric structure.
- The heaviest wipes, 150 $g.m^{-2}$, consistently yielded greater bacteria removal efficiency than the 50 and 100 $g.m^{-2}$ wipes (more fibers, more contacts on surface, more removal).

Conclusions

- Best practice for infection control should involve

- use of heavier weight
- regenerated cellulosic wipes
- impregnated with biocide
- with as much wiping pressure as possible.

Andersen, B. M. et al. 2009. Floor cleaning: effect on bacteria and organic materials in hospital rooms.

https://www.journalofhospitalinfection.com/article/S0195-6701(08)00389-7/pdf

Objectives

- To examine the load of organic materials and bacteria (colony-forming units: cfu) on the floors in patient rooms during ordinary use.
- To compare the results of two different ATP devices.
- To study the effect of four floor cleaning methods on the presence of organic materials and bacteria.
- Methods: dry, spray, moist and wet mopping.

Methods

- For assessment of soiling: ATP (from floor) and microbiological samples (from floor and air).

- An SAS air sampler was used to take air samples before and after cleaning.
- Agent: detergent (Allrent) and water.
- Four two-bed rooms, floor material: vinyl
- Swep mops, moved in a figure of 8
    - dry mopping: 50 cm, 100 % microfibre
    - spray mopping: 50 cm, dry mop, 95 % microfibre, 150-200 ml water with detergent was added to the floor before washing
    - moist mopping: mop as above, was moist after washing at temperature up to 85°C and centrifugation for 3-5 min, put in a clean plastic bag and placed in cooler until next morning
    - wet mopping: Blue Swep mop, polyester fibre 50 % and viscose 50 %. The mop was moistened in 3 l detergent water 40°C before washing over the area, followed by dry mopping over the same area, but inside the wet area.

- Sampling

- Just before, and within 10 min after cleaning.
- Floor samples were not taken from visibly stained areas.
- ATP samples were taken first, then the microbiological samples.
- Samples were taken at three different positions before and after cleaning.

Results

- Organic soil removal

- Presence of organic materials varied between rooms and days.
- All methods reduced organic material on the floors, but wet and moist mopping seemed to be the most effective.
- Cleaning reduced organic material to 5-36 % of the level present before cleaning, depending upon mopping method.

- Removal of microbes

- Bacteria on the floor showed a large day-to-day variation.
- Before cleaning, the mean bacterial count was 83 cfu/20 cm^2.
- A mean of around 60 % of cfu was removed by dry, moist and wet mopping, but only 30 % by the spray mopping.
- All four methods reduced the bacteria on the floor from 60-100 to 30-60 cfu/20 cm^2.

- **Mopping effect on cfu/m^3 air**
    - No significant difference between the four mopping methods concerning effect on bacteria in air but after mopping, the mean numbers of cfu/m^3 air increased for all four methods.

CLEANING FREQUENCIES

Bogusz, A. et al. 2013. How quickly do hospital surfaces become contaminated after detergent cleaning?

https://www.sciencedirect.com/science/article/abs/pii/S1835561716300758

Objective

- To determine the effect of detergent-based cleaning on microbial load at near-patient sites on one ward over a 48 h period.
- In a care-of-the-elderly assessment and rehabilitation ward.

Cleaning

- Cleaning with fresh disposable detergent wipe (Tuffie detergent wipes, UK).
- Wipes contain a mixture of non-ionic constituents at neutral pH.
- Cleaning bed-frame components posed few practical problems: gaining access to the bedside lockers and overbed tables was difficult due to the quantity of patient belongings.
- The quality of cleaning was standardised by preliminary training and assessment using microbiological methods.

Methods

- Lockers, left and right bedrails and overbed tables in 30 bed spaces were screened for aerobic colony counts (ACC) and staphylococci (methicillin-susceptible and methicillin-resistant *Staphylococcus aureus*: MSSA/MRSA) before detergent-based cleaning.
- Sites were rescreened at: 1, 2, 4, 8, 12, 24 and 48 h after cleaning.
- Microbial growth was quantified as number of ACC/cm^2 and presence of MSSA/MRSA at each site.

- The study was repeated 3 times at monthly intervals.

Results

- There was a significant reduction in average ACC (360 sites) from a pre-clean level of 6.72 ACC/cm^2 to 3.46 ACC/cm^2 at 4 hours after detergent-based cleaning ($P < 0.0001$).
- Average counts increased to 4.89 ACC/cm2 at 24 h and 5.27 ACC/cm^2 at 48 h for all sites.
- Levels on bed rails and lockers, but not overbed tables, fell below a proposed standard (5 cfu/cm^2) for 24 h after cleaning.
- MSSA/MRSA decreased 2–4 h after cleaning before increasing but failed to reach pre-clean levels.

Conclusions

- Detergent cleaning reduces ACC at near-patient sites on a hospital ward.
- *S. aureus* (including MRSA) was not completely eliminated but showed a similar pattern of decrease.
- Microbial burden at high-risk sites beside the patient could potentially be controlled by daily cleaning with single-use detergent wipes.

PERSONAL PROTECTION

Tahir, S. et al. 2018. Transmission of Staphylococcus aureus from dry surface biofilm (DSB) via different types of gloves.

http://processcleaningsolutions.com/pdf/transmission_of_staphylococcus_aureus_from_dry_surface_biofilm_dsb_via_different_types_of_gloves.pdf

Objective

- Do gloved hands of healthcare personnel (HCP) become contaminated with dry-surface biofilm bacteria and hence may transmit bacteria associated with healthcare-associated infections (HAIs).
- Is the result different if the biofilm is treated with neutral detergent simulating cleaning.
- Transmission was tested with nitrile, latex, and surgical gloves.

Results

- Bacterial cells were readily transmitted by all 3 types of gloves.
- Sufficient *S. aureus* to cause infection were transferred from 1 DSB touch up to 19 consecutive touches.
- 6 times more bacteria were transferred by nitrile and surgical gloves than to latex gloves (P <.001).
- Treating the DSB with 5% neutral detergent (simulating cleaning) increased the transmission rate of DSB bacteria 10-fold.

Conclusions

- *Staphylococcus aureus* incorporated into environmental DSB and covered by extracellular polymeric substances readily contaminates gloved hands and can be transferred to another surface.
- These results confirm the possibility that DSB contributes to HAI acquisition.

Phan, L. T. et al. 2019. Respiratory viruses on personal protective equipment and bodies of healthcare workers.

https://pubmed.ncbi.nlm.nih.gov/31668149/

Objective

To characterize the magnitude of virus contamination on personal protective equipment (PPE), skin, and clothing of healthcare workers (HCWs) who cared for patients having acute viral infections.

Results

- 31% of glove samples, 21% of gown samples, and 12% of face mask samples were positive for virus.
- Among the body and clothing sites, 21% of bare hand samples, 11% of scrub samples, and 7% of face samples were positive for virus.

Conclusions

- Healthcare workers are routinely contaminated with respiratory viruses after patient care, indicating the need to ensure that HCWs complete hand hygiene and use other PPE to prevent dissemination of virus to other areas of the hospital.